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EDITORIAL

FRUIT TREE PROPAGATION

THE Third Technical Communication of the Imperial Bureau of Fruit Production describes investigations on the standardization of citrus trees by propagation methods. A chapter from it is published in this number. The whole booklet deserves to be studied by those interested in the propagation of perennial trees and bushes, whether they do so for the production of fruit or other commercial products from them. It affords interesting material for the consideration not only of the citrus grower but of the planter of rubber, coffee, cocoa, and other such crops. It demonstrates what has not been sufficiently appreciated in the past that when a good parent has been selected from which to propagate there is usually a great deal of careful technique required both in the attempt to perpetuate its kind by seed and by vegetative reproduction to ensure that offspring carrying the desirable qualities are secured. We have been too accustomed to think that the germination of a seed results in a plant that contains the elements of its two progenitors—the egg cell and the pollen. That is now known not necessarily to be the case in many horticultural plants of which the citrus family, the mango, and coffee are examples. It is established that whilst the fertilised egg cell within the seed of plants usually does give rise to an embryo, yet non-sexual cells of the body of the seed may take upon themselves the propensity to multiply and grow into a new embryo plant. The result of this is that from such seeds as show this phenomenon, and it is to be noted that the seeds of all plants do not, there can be embryos of two kinds one containing the elements and hereditary properties of two parents and the other containing those of only one that being the parent upon which the seed

was borne. Whilst usually only one sexually produced embryo grows from each seed there may be several of the vegetative or mono-parent type. This explains one aspect of the variation in the types of citrus and other trees commonly noticeable in our orchards and plantations. It is an addition to our knowledge concerning segregation of parental characters and types beyond that previously possessed of such in generations derived by the process of fertilisation. Armed with this knowledge and that to be gained by studious observation it is now possible in some cases to pick out in the nursery the seedlings derived from a sexually produced embryo and those that have arisen as it were by a process of the sprouting of the parental portion of the seed. There may be marked differences between them. The possibility of elimination of the undesired types in this way from among seedlings in the nursery so as to leave us stocks for budding of a uniform kind is a most important advance in horticultural knowledge. In the past the method of securing this was by taking pieces or cuttings from the parent tree.

The importance of obtaining uniformity in the stocks upon which to bud or graft cannot be over emphasised if uniformity in the final product is to be attained. Whatever the influence of stock upon scion may be, provided all the stocks in a plantation be the same that influence will be similar throughout.

The study of the influence of the stock, however, upon the scion is one receiving considerable attention, and advance in our knowledge of this subject is to be hoped for.

In the selection of budwood, as of stocks, great care is to be taken to secure uniformity as even upon the same tree a phenomenon of bud variation may play a part introducing variation. The securing of a uniform scion is just as important as that of a uniform stock. The influence of the scion upon the stock is another line of investigation to which much attention is now being given. Upon the same stock a grafted sweet-orange scion or top will cause a deep root system whilst a lemon top produces shallow rooting. The sweet-orange top results in a comparatively high percentage of magnesium being found in the bark of the stock upon chemical analysis, whilst a low percentage results when the top is that of a lemon.

In view of the attention that is being paid to fruit cultivation in Ceylon at the present time opportunity may here be taken once more to reiterate the advice not to plant seedling trees but stocks grafted or budded with selected material.

THE CULTIVATION OF FRUITS IN CEYLON WITH CULTURAL DETAILS—X

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GROUP E

SOME FURTHER FRUITS FOR UP-COUNTRY (4,000 FEET AND OVER)

(4) THE CAPE GOOSEBERRY (*Physalis peruviana*).—The botanical name for the genus infers a bladder and has reference to the enlarged bladder-like calyx which encloses the fruit. It belongs to the same family as the potato and the tomato and as a fruit for both dessert and cooking purposes has much to recommend it. Where largely grown it is in ready demand for jams and preserves.

In habit it resembles a climber more than a shrub and is grown best if support is afforded the plant in the way of a fence or trellis. It is indigenous to Peru and Chili but is commonly cultivated in sub-tropical and warm temperate countries and in the hill districts of Ceylon and India.

It is not however very well known in Ceylon and deserves a much wider cultivation. It is adaptable to a wide range at elevations of three thousand feet and above and is suited to most soils though it prefers a well drained sandy soil of fair humus content.

The Cape Gooseberry is, in warm temperate countries, treated as an annual but in the sub-tropics and hills of the tropics is best treated as a perennial. The plant is straggly in habit and rarely attains more than 3 feet in height, but when well grown gives very heavy crops. The fruits range in size from $\frac{3}{4}$ to 1 inch in diameter, roundish in form, the flavour is sweet and pleasant but slightly acid, and when ripe is yellow in colour.

Seedlings are mostly true to type and the best seed should be selected and sown in a prepared bed or in boxes, and preferably under cover. Germination is fairly rapid and seedlings from beds can be put out in permanent sites on attaining a height of 3 inches or so. Where sown in boxes or pans transplanting into beds in the small stage at 3 inches apart is advised, and later the seedlings can be transferred to their permanent quarters. In each case plantings should be made at 3 feet apart and some form of support afforded them.

The fruits fall when ripe and if collected and stored under dry conditions can be kept in excellent condition over a considerable period but the enlarged calyx which surrounds the fruit should be retained. This should prove of considerable advantage in handling and transport of this fruit if the plant be cultivated on any large scale.

The allied species (*Physalis pubescens*) known as the Ground Cherry and also as the Strawberry Tomato and the Musk Tomato produces excellent fruit, but it has a great drawback in that it rarely grows erect and is very prostrate in habit more resembling a ground cover plant. It is more difficult to cultivate and demands a fairly large area over which to roam, and the Cape Gooseberry is therefore, because of its more erect habit, the better species with which to persevere.

(5) THE MOUNTAIN PAPAW (*Carica candamarconsis*).—A near relative of the low-country papaw and both as a fruit and ornamental plant is a useful acquisition, its introduction dating back to 1880. It is a native of the highlands of Central America where it thrives at an elevation of six to ten thousand feet, and in Ceylon has now become semi-naturalised at the higher elevations, grows freely, and produces an abundance of fruit.

It does not appear to thrive or fruit below 4,000 feet and is a fruit for the high elevations only of Ceylon. Its possibilities, by hybridising with the low-country papaw, have not to date been ascertained but such, if successful, should extend the area of its cultivation and such hybrids should improve upon the quality of the present up-country papaw.

The tree resembles in growth and fruit its low-country relative, attaining a height of 8 to 10 feet. The fruit is much smaller than the papaw, usually 3 to 4 inches in length, being much the same shape as the true papaw and the flesh yellow in colour. The fruit is somewhat sweetish and slightly acid and though such can be eaten raw with the assistance of a little sugar. It is much better appreciated when stewed. It makes good jams and jellies also and is, like the true papaw, also considered to be particularly good for dyspeptics.

The tree has no particular soil requirements, being very hardy and adaptable and thrives best in good loamy or well worked garden soil in which a proportion of cattle manure, leaf-mould or such humus is incorporated. A certain amount of moisture is required by the plant and this, owing to the elevation to which it is limited in Ceylon is generally available.

Propagation is by seed as with the true papaw and can either be sown at stake or in boxes under cover. Growth is fairly rapid and where sown other than at stake the seedlings should

be planted into permanent sites on attaining a height of 4 to 5 inches, the planting distances varying from six to eight feet apart.

(6) THE TREE TOMATO (*Cyphomandra betacea*) also known as the Gas-Takkali, S. is a rather succulent to semi-woody shrub of Peru and neighbouring countries where it forms a miniature tree of 6 to 8 feet height at elevations varying from 5,000 to 8,000 feet. It is a close ally of the ordinary tomato. It was first introduced to Ceylon about 1882 and has now become a well established plant in up-country districts as well as in parts of India.

There is a regular demand for the fruits in up-country markets and if this tree were more extensively cultivated there is little doubt but that a large demand would arise from the markets elsewhere in the Island, particularly as this fruit bears transportation so well.

The tree has large fleshy leaves and bears smooth skinned oblong to egg shaped fleshy and succulent fruits in clusters at the end of the bunches. The fruits are 2 or 3 inches in length and of two varieties, one a reddish yellow, and the other a deep purple in colour when ripe. Both varieties are much relished by many people when quite ripe and eaten raw, and as a stewed fruit has much to recommend it. They are also used to some extent in the making of jams and jellies.

In the up-country districts of Ceylon the tree often attains a height of 10 feet and though at present restricted to the higher elevations, there seems no reason why this fruit should not be profitably grown at an elevation as low as 2,000 feet provided a good soil and well drained position is afforded it.

The plant is very robust and easy to grow, yields fruit in its second year and continues to give good crops for a number of years, the fruiting season usually being during the dry north-east monsoon months.

It requires a good loamy soil and moderate rainfall. It is propagated by seed and a high germinating percentage is usually obtained. If sown in beds or boxes the seedlings should be potted into baskets or bamboos on attaining the second pair of leaves and can be planted into permanent sites, 10 ft. by 10 ft., at a very early age. At Peradeniya such seedlings attain this stage in 3 months from sowing but at higher elevations progress will be proportionately slower.

(7) Where fruit growing in up-country districts is undertaken the cultivator does, sooner or later, turn his thoughts to the fruit trees of the temperate zone, namely Apples, Pears, Plums, Apricots and Nectarines, but Ceylon—even with its seemingly temperate conditions up-country—is still within the

tropics and the wintering season, so essential for these fruits is lacking, strong monsoon winds and heavy rains being further drawbacks to the cultivation of such fruits and in the majority of cases little satisfaction is obtained.

The Peach and the Pear have possibilities and the Peach has already been dealt with. The Pear flourishes in the up-country districts in the form of a large but hard fruit fit for cooking purposes only, and not too well flavoured at that. The date of its introduction is in doubt but it is well established in up-country gardens and thrives with little attention. Its possibilities as a stock on which to graft better varieties have not yet been put to the test but there is little doubt that an improvement in pear cultivation would thereby result.

The European Pear (*Pyrus communis*) has an enormous number of varieties or horticultural forms of which many have evolved as hybrids or chance seedlings and are cultivated throughout Europe and North America where the pear is commonly grafted on the Quince, the wild pear or free stock. In Northern Asia the usual stock is the Quince, its own seedlings, and the wild Chinese Sand Pear. (*Prunus sinensis*), the latter being reputed to be particularly blight resistant, whilst the Quince is used chiefly for dwarfing effect. Hybrids between the European and the Chinese Sand Pear have been obtained in America and the well known "Keiffer" and "Le Conte" owe their origin to this cross. No progress in establishing good varieties in this country is likely to be made by the mere import of good varieties, for these are most difficult to establish on the root stock used by growers outside the Island. It is very necessary that a root stock suited to the conditions of the country such as the present common cooking pear should be used as the stock and the imported plant used for scion purposes.

As a means of improvement on the present cooking pear, imports of certain well known varieties known to thrive in localities where the winter is negligible are the first necessity, and "Keiffer's Hybrid", "Beurre Bosc", "Le Conte" and the "Bartlett" pear are varieties suited to a wide range of conditions, the "Beurre Bosc" and the "Bartlett" being essentially fruits for dessert purposes.

In up-country districts propagation of the present cooking pear is by rooted cuttings, but own seedlings can be recommended as a more satisfactory means of raising stock plants, and such should be available for budding or grafting from 2 years of age, the usual method employed elsewhere being by budding or grafting. Where budded in the nursery the plants should be large enough for transport to permanent sites at three years of age.

Growth of the tree is not rapid and is more often stunted, nor does the tree attain any great size, and 15 feet by 15 feet should be ample planting distances.

Little can be said at this stage with regard to pruning as the principles vary remarkably among the different varieties of pear in cultivation and experience must be the guide when it is ascertained to what extent the common cooking pear, used as a stock plant, meets the requirements.

CONCLUSION

Throughout these articles it will have been noted that propagation by vegetative means has been much emphasised and the properties of the root stock in the improvement of fruit culture in the Island is one of the most important items that has yet to be studied. The grafting and budding of fruits is comparatively new to Ceylon but is an ancient practice in many other countries though the full importance of this operation has not, even there, been realised until recent years.

In the present early stages of fruit propagation here, it is advisable to repeat once again the fundamental principles on which such grafting and budding is advocated and why it has such preference over the seedling. The latter, as regards the propagation of the more choice fruits cannot be relied upon, as some of the best fruits produce little or no seed. In others the flowers are pollinated by neighbouring trees of inferior quality, resulting in seeds and seedlings of mixed parentage, or in other words not true to type, and there are many other reasons also.

In practice, the result of grafting or budding is that a fruit tree is produced, built up of two of the same or closely related individuals—the root stock and the scion.

The chosen root stock is invariably of a type noted for its robust and strong root system and growth, its adaptability to various, or even to a particular soil, to rainfall, to temperature and to other factors. The scion is of course either a bud or woody portion of the selected variety of fruit which it is desired to propagate. The advantages of grafting or budding are that the characters of the scion are retained with some certainty, it is a means towards uniformity in an orchard, the tree is brought into bearing at an earlier age than the seedling and in certain required instances diœcious trees can be intergrafted to assure more perfect pollination of the flowers.

A certain amount of data has already been acquired as to suitable rootstocks for the various fruits and is embodied in our articles, but much remains for future experiment.

Stock characters have been elucidated in many instances and the information put to very practical use. That the Sour Orange is a sound stock for most Citrus is well known, it being resistant to many root troubles, and latterly in the West Indies it has been the means of resuscitating the Lime industry which but a short time ago stood in danger of being completely wiped out owing to wither tip disease. In Ceylon the country Mandarin appears to be the best of all Citrus so far experimented with in its resistance to Citrus Canker. Soursop has proved to date at Peradeniya a very sound stock for the Cherimoya, the Alligator Apple for the Ilama and some other Anonas, the common local mango for the more choice mangoes, the local Avocado for West Indian and Mexican varieties of the fruit, the Goraka and Cochin Goraka for the Mangosteen, and so on.

All this however is mostly only one aspect of the subject—that these fruits can actually be budded or grafted one with the other. Full compatability of the stock, its effect upon the scion or the scion on the stock, to what extent one stock is better than another, and whether budding low or high on the stem of the stock affects the character of the scion, the causes of bud overgrowth and many other problems of the kind as bud variation and similar phenomena, have to be studied. With deciduous fruits the European horticulturist grafts his trees on the stem of the root stock on the assumption that the stem of the stock plays an important part, whilst the American horticulturist in the main grafts on the root of the seedling stock on the grounds that a greater amount of scion influence is thereby gained.

Tropical fruits unlike the fruits of temperate countries have received little attention as regards selection and improvement, but by vegetative propagation of the best varieties on the lines already stated, considerable progress in the desired direction is to be obtained, pending more complete knowledge of stock influences and how these may best be turned to account.

THE CULTIVATION OF DWARF FRENCH BEANS IN HARISPATTU

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THE growing of Dwarf French Beans (*Phaseolus Vulgaris*), *Bonchi*, S. has extended in Harispattu within the last few years. From the stage of a kitchen garden vegetable its cultivation has assumed a stage of a field crop of considerable monetary value to the village growers, and, during the last few years, in the Katugastota area —one of the chief centres where the crop is grown on a large scale—an extent of well over 150 acres are annually grown with this crop on a field scale.

There are a number of families chiefly in Haloluwa and Kondadeniya whose sole occupation is bean cultivation. They are comparatively large scale growers, and plant from three to five acres in beans per season. Smaller growers depending on quarter to half acre, are in the majority. Last year the extent under preparation for planting in April-August in Kulugammana Siya Pattu alone, was estimated at about 80 acres, and, about three hundred people were likely to be engaged in the industry.

In addition to the high land that has not been brought under permanent cultivation, paddy lands that are dry (Goda Liyaddes) and remain uncultivated in paddy during the Yala season, are utilised for growing beans.

Beans are grown throughout the year, but those who grow the crop on a large scale, do so in two recognised seasons: the first commencing in April and ending in August; June-July being the most favoured during this season—and the second commencing in October and lasting to January; mid-November and mid-December are avoided for planting out.

The crop is easy to raise. Beans grow on all ordinary soils provided they be well drained. The soil is dug to a depth of about 6 inches in the dry weather. This operation is called "Binneguma". It is then allowed to 'weather' for a month

or sometimes, two. With the early rain it is broken up again and worked. This operation is called "Deketuma". Immediately after, or a few days later, levelling and draining operations are carried out, and planting follows.

Generally two seeds are planted per hole about two inches deep, 5 to 6 inches apart. The general practice is to make the holes with a pole which is pointed at the end. A man carrying this pole, sticks it hard in the prepared soil making the hole. An experienced workman does this quickly and accurately, keeping to regular distances. Another person, ordinarily a boy or woman, follows, dropping the seed in the holes and at the same time covers them by the foot by pushing in the soil and pressing it a little. An experienced 'pole-sticker' and a woman will plant from 8 to 10 measures of seed in a working day. Seed rate differs from one and a half to two bushels per acre.

Seed supplies are obtained from Welimade district in Uva, and from imported seed which comes mainly from India. Prices vary from Rs. 15·00 to Rs. 25·00 per bushel, according to the supplies available and the demand. At the present time owing to shortage in stocks, dealers are demanding 90 cents per measure which works out at Rs. 25.20 per bushel.

Beans grow fast and the first picking is made in 45 to 48 days. From a well cultivated field, five to six pickings at intervals of 3 days, can be secured. Yield varies considerably. Sometimes from a well cultivated field of one acre, half a million bean pods can be gathered in a good year. A fair average in this district is about three hundred and fifty thousand pods. There have been instances when with good cultivation, a crop of over three quarters of a million pods have been gathered.

Boys, girls, and women are generally employed in plucking. They are paid by the rate, and are expected to pluck 8,000 pods a working day, and are paid 25 cents per 8,000. Expert pluckers total twelve thousand per day.

Prices vary. In some years, prices have gone down to 25 cents per thousand pods. In 1927 and 1929 the prices ruled between Re. 1·00 to Rs. 1·25 for several months, and came down to 80 cents during July-August when large quantities were marketed. A curious fact is that buyers, while they have refused other kinds of vegetables when produced in large quantities, have never refused beans. Records show that on many occasions the two chief buyers at Katugastota have taken between them

6 million pods a day at an average price of 40 cents per thousand. Though sold by the thousands they are generally not counted but the number estimated by weighing. The average weight of thousand bean pods is about 7½ lb. The better sized ones weigh up to 9 lb. per thousand. Early crops in 1931 were sold at 65 cents, but as the main crop came in prices went down to 30 cents.

The following instances of many carefully investigated crops during 1931, give interesting facts and figures:

Case A. Kondadeniya

1. Extent, 2 pelas sowing or 1 acre

2.

Cost of "Binneguma"	...	Rs. 15·00
Cost of "Deketuma"	...	,, 10·00
Cost of levelling, draining and forming large beds	...	,, 8·00
Cost of planting, Rs. 6·00		
Cost of seed, Rs. 28·60	...	,, 34·60
Cost of plucking	...	,, 17·75
Total Cost	...	Rs. 85·35

3. Return

1st Picking	165000	@ cts. 60	per 1000	Rs.	99·00
2nd do.	97000	@ cts. 65.	do.	,,	63·05
3rd do.	66000	@ cts. 55	do.	,,	36·30
4th do.	25000	@ cts. 40	do.	,,	10·00
5th do.	16000	@ cts. 40	do.	,,	6·40
6th do.	7000	@ cts. 30	do.	,,	2·10
		Total Return			Rs. 216·85
		Profit			Rs. 131·50

B. Nikatenne

1. Extent, ½ an acre

2.

Cost of "Binneguma"	...	Rs. 6·00
Cost of "Deketuma"	...	,, 4·00
Cost of Levelling, draining and forming large beds	...	,, 1·50
Cost of planting. Rs. 3·50		
Cost of seed Rs. 15·40	...	,, 18·90
Cost of picking	...	,, 6·50
Total Cost	...	Rs. 36·90

3. Return

1st Picking.	78000	@ cts. 65	per 1000	Rs. 50·70
2nd do.	43000	@ cts. 65	do.	,, 27·95
3rd do.	18000	@ cts. 70	do.	,, 12·60
4th do.	6000	@ cts. 60.	do.	,, 3·60
5th do.	2000	@ cts. 60	do.	,, 1·20
6th do.	1000	@ cts. 40	do.	,, ·40
		Total Return		Rs. 96·45
		Profit per ½ acre		Rs. 59·55

C. Haloluwa

1. Extent, 1 acre

2. Cost of "Binneguma" ... Rs. 18·00
   Cost of "Deketuma" ... ,, 12·50
   Cost of Levelling, draining and forming large beds ... ,, 6·75
   Cost of seed Rs. 24·40
   Cost of planting Rs. 4·80 ... ,, 29·20
   Cost of plucking ... ,, 16·20
   Rs. 82·65

3. Return 405000 @ cts. 50 per 1000 Rs. 202·50
   Profit Rs. 119·85

SOIL EROSION IN CALIFORNIA: ITS PREVENTION AND CONTROL

[This is extracted from Bulletin 538 issued by the University of California, College of Agriculture. Its practical treatment of the subject will probably be of interest to those of our readers who have experience of the necessity for Soil Erosion Control.—Ed. *T.A.*]

INTRODUCTION

SOIL erosion is an active and important agency in the destruction and the depletion of one of the most valuable natural resources. It has, within the last decade, become recognised in America as a problem of national importance and is now attracting the attention of the soil scientists and agricultural engineers, as well as the farmers in many sections of the country. The earlier studies on erosion control in this country were made along the Atlantic coastal plain and Piedmont section of the Appalachian States, but in more recent years this work has extended westward to include most of the Mississippi Valley States, Texas, and Oklahoma.

The 1930 Agricultural Appropriation Bill carried an item of $160,000 for the study of soil erosion problems by the United States Department of Agriculture, either independently or in co-operation with state, county, or farm organizations. To facilitate the carrying out of this project, the country was divided into nineteen regional soil-erosion areas, in each of which may eventually be established a soil-erosion experimental station. Several of these have already been established and are in operation.

There is an inclination to take a narrow view of the damage done by erosion and to consider only the most obvious results. The formation of gullies and the damage caused by the deposition of eroded material on cultivated fields, highways, or drainage ways, are truly visible and often spectacular, but may be of less economic importance than some other damages such as those caused by sheet erosion, loss of moisture, loss of fertility, decrease in yield and nutritive value of crops, excessive cost of cultivation, and many other less tangible results.

In its effects upon agricultural and pastoral lands, erosion does not stop with merely removing the upper soil layers and exposing the sub-soils, changing vast areas from productive loams and sandy loams to unweathered and unproductive clays, but goes on to the point of actually destroying these lands by deep channels or gullies; it wastes not only soil but also water; it not only destroys the land eroded but may also greatly reduce the agricultural value of the land on which the eroded material is deposited; it not only reduces the size and number of plants that can be grown but also diminishes the nutritive value of those which are grown, and at the same time increases the cost of producing them.

Erosion is gradually dawning upon the agricultural consciousness of America as one of the major problems. Like a mighty octopus a gully will reach out its tentacles and swallow whole farms with insatiable appetite. Less ostentatious, leech-like, sheet erosion sucks the life blood of agriculture—the top 6 inches of soil. So insidious is its attack that its importance seems to have been discovered only recently by students of erosion. Many a farm has washed and is washing out from under the owner's feet without his being aware of it. Erosion is a world problem, few soils are immune or evenly highly resistant to it; cultivation stimulates it; even slight slopes encourage it. We might have learned to appreciate and guard against the depredations of erosion from the history of former civilizations. The fact that we have not exemplified adages to the effect that experience teaches a dear school and that a student for it is born every minute.

Erosion is farm relief with a vengeance. It is rapidly reducing the surplus production capacity of American agriculture. But while it is throwing marginal farms hopelessly below the margin, it is likewise taking its toll from good farms; and when agriculture needs more production capacity it will not be able to bring back the soil and plant food which is now slipping away to the sea.

If the chief capital of its agriculture is only 6 inches thick and is being washed away more than twenty times as fast as it can be renewed by Nature, how long will it take America to wake up and do something about it ? Any institution or individual guilty of such gross neglect in the handling of other forms of public trust would be prosecuted. But soil erosion is allowed to continue as if it were strictly a personal matter to each individual landowner.

If a great fire were sweeping the country, doing damage at the rate it is being done by erosion, an army of fighters would be mustered to combat it. But for soil erosion a few scattered sentinels are posted to observe the destruction and give the alarm.

CAUSES OF EROSION

Soil erosion is caused by the action of water moving over the surface of the soil, thereby transporting particles of soil which have been loosened from one place and depositing them in another. The point of deposition, however, may be many miles from the point of acquisition.

The power of moving water to scour or loosen soil particles varies as the square of the velocity, and the power to transport this material varies as the sixth power of the velocity. It is therefore obvious that anything which influences the velocity of moving water also influences its erosive power.

Not all soil erosion is man-induced, nor can that which is so induced be entirely prevented. There is no doubt that the influences of man have very largely contributed to the acceleration of erosion, but his influences may also be profitably directed toward both remedy and prevention. Wherever water runs down hill there will be erosion; otherwise, there would be no alluvial or water-transported soils filling the valleys and providing the most valuable agricultural lands.

Curiously enough, greater effort is made to prevent the deposition of eroded material on other lands than to prevent the erosion itself. It is not an uncommon sight to see levees, dikes or ditches constructed to prevent overflow on flat lands and for the diversion of silt-laden waters into creeks and rivers. Much less often are measures taken to prevent runoff and its accompanying erosion on the lands which are being depleted of both water and soil. At the present time, therefore, very little benefit can be said to accrue to farmed lands by the building up or accumulation of soil from eroded areas.

Normal erosion may be described as that which takes place under natural undisturbed conditions of soil, rainfall, slope, and vegetative cover, and although certain combinations of these factors may occur which will for a time greatly accelerate this action, it is usually slower and less destructive than erosion to which man's activities have been a contributing factor. As variable as the rate of normal erosion may have been in the past ages, there is ample evidence to show that at the present time erosion has been greatly accelerated through man's influence. Only that erosion for which man is either directly or indirectly responsible need be discussed here, and for only such erosion need remedial or preventive measures be applied.

Vegetative cover is probably the most important factor of all those influencing erosion. The amount and type of vegetative cover is influenced by the amount and distribution of rainfall and by temperature, and this relation is so adjusted that for any particular condition the destructive forces of erosion are balanced by the re-constructive forces which govern the re-growth of vegetation, formation of new soil, etc.

Vegetative cover is susceptible of important modification by man in his attempts to gain a livelihood by tilling the soil or by grazing his flocks. Its removal or alteration by man, or his influences, may be placed in four general categories:

1. Cultivation and preparation of land for agricultural purposes.
2. Pasturing of stock.
3. Lumbering and other non-agricultural land-clearing operations.
4. Fire.

It is obvious that native vegetation cannot be maintained intact on cultivated fields, and that the planted crops must be tilled in order to produce the maximum yield. There may be occasions where the growing crops, as for instance, hay and grain, are as great a protection to the soil against erosion as the native vegetation, but many times these are not at a growth stage which will afford much relief when most needed. Even with such crops as grain, it is necessary to plough, cultivate, and otherwise disturb the soil so that the previous crop residue is of less value in reducing erosion than it would be on undisturbed soil. Row crops, both annual and perennial usually require that the soil between rows be free from vegetation and therefore more subject to erosion.

Plants have a three-fold influence as a protection to the soil against the destructive action of running water. The stems, leaves, and branches intercept the rainfall before it touches the soil, thus breaking up the force of its fall and the resulting pounding action which always takes place on

bare hard surfaces. Raindrops, therefore, reach the surface of the soil at greatly reduced velocities. Vegetation tends to minimize the concentration of rain water on the surface and its collection into small streams or rivulets. The roots of vegetation hold the soil particles together.

Both living and decaying roots open up the soil and form small passageways into the deeper layers whereby water is more readily absorbed by the soil and allowed to pass into the subsoil. Water which has penetrated into the soil seldom aids in erosion. Therefore, the more water that a soil can absorb and the more rapidly this takes place, the less will be the eroding power of that which remains. If all rain water was absorbed as fast as it falls, there would be no erosion.

The remains of vegetation are in themselves highly absorptive and retain, for a period at least, a considerable part of the water which falls as rain. Cultivation disturbs the natural soil and the interlacing effect of growing and decaying roots, often materially changing the soil structure and very frequently leaving the surface not only without any protection but also actually leaving it in a condition that promotes erosion rather than retards it. When the last cultivation takes place up and down the slope, small channels are left in which water may accumulate and start its eroding action.

When grazing lands are properly pastured, there will always remain sufficient cover to protect the soil from excessive erosion, but when too heavily stocked, the cover is so completely removed that adequate protection no longer exists. When food is scarce grazing animals are forced to search repeatedly over the same ground for food, thereby not only disturbing the surface soil but also actually cutting up and destroying the roots of grass and other herbage. The action is very similar to cultivation, with the result that erosion may take place before another crop has been established.

Land clearing and lumbering removes the protecting cover from large areas and in some cases may result in serious erosion. This is particularly true where the slopes are steep and where clearing is complete. Some hillside residential property has been seriously damaged because the brush and timber have been removed and erosion has been uncontrolled.

Very striking and spectacular examples of erosion often follow fire. Reservoirs have been filled with debris from burned hillsides; roads, bridges, and growing crops have been destroyed by floods coming from burned areas; and the burned lands are often so badly gullied and denuded of surface soil that they remain bare for years as a constant reminder of their destruction and a constant menace to mankind.

EFFECTS OF EROSION

The most obvious effect of erosion is the formation of gullies. Some of these are so deep and wide that the destruction of the land is complete, and nothing can be done to restore it to productiveness.

In other places the gullies are smaller and may be in part restored by check dams and settling basins. Few of these gullies have been formed for long periods, and most of them are of comparatively recent origin.

There is no fixed difference between what is termed "sheet erosion" and "gullying." It is rather a matter of degree of destruction or the size of the gullies. Usually when the gullies are shallow enough to be crossed by cultivating tools and can be filled in by cultivation, the erosion is considered as sheet erosion. This type may be almost, if not entirely, as destructive as the former, and when fields become so poor as to be abandoned or neglected, deep gullying usually follows. The cultivation of fields cut up into irregular shapes, is difficult and expensive, and in such a condition protection will probably cost more than the land is worth.

Fields from which as much as an inch of soil is washed away annually are not uncommon. Abandoned fields are numerous. During the rainy season the fields and orchards of this section are cultivated after each storm and the small gullies which have been formed are filled in with loose material only to be washed away again by the next rain. Frequently the material eroded from one field is deposited on another, thus spreading the destruction to two areas. It usually takes considerable time for newly deposited soil material to become sufficiently incorporated with the underlying soil and to become good fertile land.

Overgrazing of pasture lands is an important factor in the erosion of untilled areas. As has already been stated, the relation of cover to rainfall is very delicately adjusted and even in those areas where the rainfall is scanty the grass cover is sufficient to protect the lands on which it grows from excessive erosion. Any major disturbance in one factor of this relation is likely to increase the influence of the other factor to the point where it may become destructive. Obviously, the amount and distribution of rainfall or the topography of the landscape is not altered by the presence of foraging animals, but the amount of grass and brush which is permitted to grow and protect these areas from erosion can be very materially affected. After the removal of the surface soil by erosion, it has been shown that the ability of the soil to restore vegetative cover is greatly reduced and that frequently undesirable species of grass or brush are allowed to become dominant.

The type of cover which follows the erosion of pasture lands may be of such low nutritive value as to be reflected in the stock grazing on these lands; symptoms of malnutrition can be directly traced to erosion caused by uncontrolled grazing. That the products from eroded lands used for human consumption may be lacking in essential elements for normal growth and development may not be beyond a reasonable possibility.

Fire, especially that for which man is responsible, is probably the most inexcusable of the vegetation-destroying elements. Improper cultivation, overgrazing, and similar activities may in part be justified, at least temporarily, by economic considerations, but seldom can this be said of fire. Fire may so completely destroy the cover that disastrous erosion immediately follows. The increase in surface runoff as the result of surface erosion is a serious matter, where the conservation of water is so essential to crop production. On irrigated areas the deficiencies in moisture may be supplemented by artificial applications of water, but in many sections irrigation is not available. In these sections water lost by surface runoff represents a positive decrease in the amount of moisture later available for plant growth. The season of available soil moisture may therefore be lengthened

in direct proportion to the amount of water that can be saved from runoff. If there were no other reason for the prevention of soil erosion than moisture conservation, the effort would be fully justified. It is not expected that all of the rainfall can be retained or that erosion can be entirely prevented on steep cultivated fields during such excessive storms as have just been mentioned. It is, however, highly desirable that such protection as is economically feasible be undertaken.

EXPERIMENTS RELATING TO EROSION

The amount, distribution, and intensity of rainfall vary greatly from place to place. Mc.Gee estimates that about one-third of the total rainfall flows from the surface of the earth as surface runoff and the remainder enters the soil, replenishing that which has previously evaporated or been transpired through plants. It has already been shown that these figures may be greatly exceeded in many instances. Veihmeyer has shown that the losses by evaporation are insignificant when compared with transpiration, and that except for the immediate surface, evaporation losses are exceedingly small even where there is no vegetative cover. This means then that vegetation must be depended upon as the principal agency in reducing the moisture content of soils to such a point that they will absorb rainfall. Without vegetative cover a much greater portion of the rainfall will be lost by surface runoff than would normally occur. That such a condition actually occurs is readily observable from even a superficial comparison of forested or brush-covered areas with bare areas.

The most important function of plants in relation to erosion control is not the drying out of the soil through transpiration, important as that is, but rather it is the mechanical obstructions which plants and plant remains offer to the free movement of water over the surface of the soil. Lowdermilk has found that the humus resulting from plant remains is also effective in keeping the soil open and receptive of moisture by preventing the coating or sealing of the surface with fine-grained particles. By retarding the velocity of moving water and preventing or hindering its concentration, plants make it possible for more water to be absorbed by the soil. Recent unpublished work by the Bureau of Agricultural Engineering, United States Department of Agriculture, has shown that more than twice as much water will be absorbed by soils covered with undisturbed native vegetation as by soils which have been disturbed by cultivation and are bare of growing crops.

Erosion, or the carrying away of material by moving water, is governed by the amount of water, the slope of the land, and the obstacles which are placed in the way of its free movement. These three factors are interdependent and the control of any one of them affects the other two.

As rain falls upon the surface of a field the moisture is absorbed by the soil and penetrates below the surface. If the moisture falls slowly, this process may continue for considerable time, but if the rain falls more rapidly than it can be absorbed, the surface soil quickly becomes saturated, and the excess remains on the surface as free water. If the surface is level or is roughened by cultivation or organic debris, this water lies more or less stationary until it has had time to be absorbed, but if the surface is smooth and sloping, it begins to move down the slope. At first this movement is slight, but with increasing supply of water it soon gathers into tiny streams. Once this is started, the coalescing streams grow in magnitude and swiftness and eroding power as they proceed down hill.

As soon as these streams become large enough to pick up and carry soil particles of any considerable size, they begin to entrench themselves in the spaces from which the soil they carry was just removed. Entrenchment means further concentration and increased destructive power, which continues until some intervening factor develops. The intervening factor may be a change in slope which will decrease velocity, a natural or artificial obstruction or barrier which will break up the stream, or a cessation in the rain or water supply. The erosive power of clear, moving water varies as the square of the velocity, but the power to transport eroded material is much greater, furthermore, the erosive power of water carrying suspended material is directly in proportion to the amount of suspended material. It is obvious that the carrying capacity and the size of particles which may be carried is a function of the volume of the water as well as its velocity.

According to Bennett and Chapline soils high in silt, light-textured soils overlying less-absorptive heavier types, clays that undergo marked granulation and fragmentation on drying, and those low in organic matter are most susceptible to rapid denudation by sheet erosoin. Soils having unstable subsoils of sandy material are more subject to gully erosion than those having permeable subsoils of silty clay or clay loam. Soils with impervious sublayers are far more erosive than those with permeable substrata unless the sub-strata are very unstable. Studies on soils subject to severe erosion in California bear out these conclusions and indicate that light-textured sandy soils having relatively impervious heavy clay subsoils are most easily eroded, especially when the surface soils are of shallow depth. On the other hand, soils having uniform textures throughout a considerable depth of profile are, other things such as slope, rainfall, cover, and tilth being similar, less subject to erosion than those having a dissimilar surface and subsoil. Soils which are heavy textured are generally least subject to erosion, except where their heavy texture is due to the fact that a lighter-textured surface soil has already been eroded away and the present uppermost layers are in reality exposed subsoils. In the latter case the chemical composition, lack of humus, and the structure and consistence of the clay may be such as to offer little resistance to erosion.

Every soil so far examined in this state that is subject to severe erosion has been found to have surface soils ranging from decidedly acid to neutral and in many cases the subsoils are acid. Apparently those which are most acid in both surface and subsoil are most severely eroded. This is probably due to the fact that soils containing lime (basic) are flocculated, while those lacking in lime (acid) are deflocculated, and the degree of deflocculation is a measure of the acidity of the soil. Just what practical value these findings may have and how this information may be used in connection with plans for relief from erosion have not yet been determined.

Middleton has done some work in an attempt to determine wherein these soils which most easily erode differ both chemically and physically from others which do not, but his work has not yet been carried far enough to establish an altogether satisfactory method of measuring the relation between these factors and susceptibility to erosion.

EROSION, PREVENTION AND CONTROL

So much has been said regarding the importance of cover as a protection against erosion that the impression may be gained that the maintenance of cover is the only remedy. Although cover is Nature's way of preventing excessive erosion, and it might be wise for man to follow this lead wherever practical, it cannot always be done. Many crops require that all vegetation except the crop itself be removed. It is therefore necessary to resort to other methods of prevention.

Only those remedial measures applicable to agriculture land and the production of crops will be discussed. Although it is true that most of the means of erosion prevention discussed herein have not been extensively employed in California, there is ample reason to believe that they are suited to California conditions. The practical treatment of soil erosion involves prevention, control, and remedy, and, like the treatment of disease in the animal and vegetable kingdom, an ounce of prevention is worth a pound of cure. The key to the treatment, whether prevention or cure, is the same, namely, the maintenance of a proper balance between slope, cover, soil, and water.

Erosion, prevention and control is a new undertaking for most California farmers; however, the fundamental principles involved are not new, and for many it will be only a new application of these principles.

Erosion, prevention and control will be discussed briefly under three general topics—tillage, both as a separate means of control and in conjunction with other methods; terracing; and check or soil-saving dams. The various steps to be taken in each case will not be described in great detail for much must necessarily be left to the judgment of the farmer as to what will be best for his particular needs.

Contour Cultivation for Annual Crops.—Modifications in tillage practice appear to offer the greatest benefit for the least expenditure, and regardless of whatever else might be done to prevent erosion, tillage must be made a part of the scheme. One of the simplest preventives is contour cultivation, but when used as the only means of erosion prevention should be confined to slopes of less than 20 feet per hundred. Many hillsides are ploughed and harrowed with the furrow running and down hill, leaving the surface in a condition most susceptible to erosion. Sloping land, which is subject to erosion, should never be cultivated with the slope but always across it. Simply cultivating at approximately right angles to the greatest slope is not sufficient, because there are very few slopes so uniform that there will be no places unprotected if cultivation is done in this way.

With contour cultivation, strip planting, or terracing, the first step is to lay out the lines in the field and the procedure is similar in each case. The contour interval or vertical distance between lines is determined by observing the distance below the highest point of the field at which erosion becomes apparent. This indicates the distance through which water must travel under the conditions of slope, rainfall, and soil at hand before it has attained sufficient velocity and volume to erode, and can be used as a safe approximation of the proper interval. For steep slopes the vertical distance between contours can be somewhat greater than on flat slopes because for a given vertical distance there is less horizontal distance and

less area on which to accumulate water. For example, on slopes of 15 to 20 feet per 100 the contour interval may be as great as 10 to 12, while on slopes of 5 to 10 feet per 100 the interval should be 4 to 6 feet. These figures should not be taken as definite recommendations for all conditions and types of soil and climate; they may require material modification to meet the needs of any particular tract of land.

When the proper contour or terrace interval (vertical distance between succeeding lines) has been determined, lines this distance apart should be surveyed and staked out. For example, if 5 feet has been determined as the proper interval between contour or terraces, as the case may be, in a certain field, then lines should be staked out having 5 feet as the difference in elevation between them. These should not be level lines, but should be given a slight fall toward one or both sides of the field. For lines, 1,000 feet or more in length the fall at the upper end should be about 2 inches per 100 feet, increasing gradually to about 5 inches per 100 feet. For lines less than 500 feet in length, the fall may be uniform at about 3 or 4 inches for 100 feet. Short distances are more desirable; long runs should be avoided whenever outlets are available for shorter ones.

After the line is staked out, a plough furrow should follow the line of stakes, throwing the furrow slice up against the stakes. The return furrow should be thrown against the stakes on the next lower line. The ploughing then continues between these two lines until the entire strip is ploughed. The dead furrow in the centre should be opened at the ends to permit free drainage. This strip is thereafter a unit for all field operations such as ploughing, cultivation, planting, irrigation, and harvesting, all of which should be done parallel to the contour. If this is done and no cross cultivation permitted, it will not be necessary to resurvey the area each year; the old furrows can be followed instead. After two or three cultivations these furrows can be followed without difficulty.

Row crops should be planted in strips with the first row on the ridge or back-furrow and the succeeding rows, as far as the dead furrow, parallel to it. This results in a field of crooked rows and usually either short or stub rows and near the centre of the strip, but since slopes are seldom uniform and therefore contour lines are not parallel, this objection cannot be avoided. Long rows should be avoided. About 1,500 feet should be the maximum length of row and there will be much less danger of water breaking away running down the steepest slope if rows are restricted to 1,000 feet or less.

Provision must be made for removing excess water from the ends of the rows. This can be done by ending the rows along some predetermined line where the water is collected in a ditch or pipe line and carried down the slope. Considerable care must be used in providing outlets for this water because it may cause serious damage if left uncontrolled. Only a few suggestions can be given as to how this should be done; other methods may need to be devised if none of these may seem to fit the particular needs at hand. The water may be turned into a gully, if one is available, lined with rock or concrete, or thickly grown up to weeds and grass; or it may be turned into an adjoining uncultivated field and allowed to spread out over a large area. Usually such areas are themselves already

saturated and incapable of absorbing additional water so that gullying may occur there. Another method is to collect the excess water in tile lines which run directly down the slope, the water being admitted to the line through a riser located in each dead-furrow or terrace end.

Contour cultivation such as has been described, as well as that in connection with terracing, to be described later, may mean a very decided change in cultural procedure from that in common use in the region. It may preclude the use of certain heavy machinery which cannot be readily turned into short rows and narrow strips, but modifications in farm equipment and even major changes in cultural procedure can be made and are of minor importance when compared with the saving of the soil from possible permanent injury.

Strip Cropping.—Another device sometimes used in connection with contour cultivation is "strip cropping". Strip cropping consists of planting strips of densely growing or fibrous-rooted crops between strips or rows or clean-tilled crops. This method, although often highly effective in preventing erosion, should be considered as a temporary relief until means are provided for installing more permanent protection such as terraces.

The method of laying out the strips is similar in every essential to that of laying out fields for contour planting or terracing. A strip 10 to 20 feet wide of some densely growing crop is planted on the site of the proposed terrace or along the contour line. In California, where the damage from erosion occurs during the winter, the crop must be one which can be planted late in the fall and which will grow rapidly into a dense mass. Some of the vetches that are extensively used for cover-crops in various parts of the State should prove satisfactory. In irrigated areas alfalfa should be an excellent crop for the strips.

Erosion Protection in Established Orchards.—Contour tillage on established hillside orchards which have been planted on the square or triangular system offers a rather difficult problem. If the trees are small, far apart, and trimmed so that cultivation can be carried on close to the trunks, it is possible to lay out contours which can be fairly closely followed by crossing from one tree row to another, and after two or three repetitions a short or low terrace will be built up which can be easily followed in future operations; but if the trees are large or closely planted, contour cultivation may not be feasible.

If particular care is used in providing outlets for water which concentrates in low places cultivation in the tree rows most nearly at right angles to the greatest slope will often aid materially in erosion control. If such cultivation is accompanied by a modified strip cropping even greater benefit will be derived.

Probably the best type of erosion protection for a square or triangular-planted hillside orchard is a dense cover-crop. To be most efficient, it should be planted early and not ploughed until after the heavy rains are past. It is, of course, impossible to determine in advance when the rain season will be over, and many farmers are unwilling to take chances on allowing the cover-crop to remain too late. On land which can be irrigated, it is not a serious matter to leave cover-crops standing until after

the major part of the rainy season is past, but in non-irrigated areas this cannot be done without the sacrifice of considerable moisture which should be reserved for tree growth. Loss of moisture, however, even where there is no irrigation, is far less serious than loss of soil by erosion, for the soil cannot be replaced.

Tile Underdrainage.—Tile underdrainage has been effectively used to prevent erosion on certain types of soil. Soils with pervious, easily, penetrated surfaces, underlaying at a few feet in depth by impervious subsoils, respond to tile drainage better than soils having more impervious surfaces. Tile are laid just above the impervious layer in lines running across the slope. The drains intercept the water as it moves along the impervious layer and carry it away before it has accumulated in sufficient quantity to cause the whole area to slide. The principles of this type of drainage are the same as those ordinarily used for intercepting drains, and the same care should be used in their design and installation. Tile drains in combination with terraces are frequently used.

There are undoubtedly some places where the methods so far suggested are not feasible with the crops that are now being grown. In such cases it might be better to change the agriculture of the section entirely by growing new and different crops which can be grown in such a way as to save the soil. To use a single example as illustrative of this point—and there are many similar examples in California—unless some method of tillage or some soil-saving device not now used is put into common practice to lessen the erosion on the garden-pea lands around Arroyo Grande, it will not be long before these hills are so seriously depleted of surface soil and fertility and so badly gullied as to be useless for any tilled crop.

It would be better to restore these areas to native brush and grass than to continue present methods of cultivation. The idea of restoring land to its native cover is not entirely new; there are a few places particularly in Ventura County, where land that has been in beans or other annual crop has been restored to pasture with no cultivation other than that which is occasionally necessary to destroy obnoxious weeds. Unfortunately, cultivated crops were not given up on these areas until a part of their usefulness had been destroyed by erosion, so that the restoration of a desirable type of native cover may be rather slow. It is not safe to assume that land which has become unproductive for cultivated crops can be easily and rapidly restored to a pasture crop equal in value to the original native cover.

Terraces.—The terrace offers the best type of erosion protection yet devised for use on tilled land. It provides more complete protection than other methods and is adaptable to a wide range in slope, type of soil, and rainfall.

Terraces may be separated into two general groups, the bench terrace and the ridge terrace, and although there are some terraces which have characteristics common to both groups, each has a particular field for which it is best suited. The bench terrace, or as it is often called, the "true" terrace, is best adapted to steep slopes and produces a field resembling a series of stairsteps. All terraces may either be level or slope in the direction of the terrace. The sloping terrace is the more common and where irrigation is practised is a necessity.

Bench Terraces.—The bench terrace has been highly developed in portions of central and southern Europe and in the Orient, and in southern California it is popular for steep hillside orange, lemon, and avocado groves.

As used in this State, the flat or tillable part of the terrace may slope with the general trend of the field or be level in the direction at right angles to its length. Trees are usually planted near the outer edge and cultivation takes place only on the upper side of the tree. The outer slope or riser is often allowed to grow up with grass or weeds during most of the season. Sometimes during the dry season this cover is removed by hoeing. There are some bench terraces in Ventura County in which the riser is planted to ice plant (*Mesembryanthemum roseum*). This makes an excellent cover, prevents the growth of undesirable weeds, and renders the bank practically immune from washing.

A good contour map of the area to be terraced, although not absolutely essential, is a great aid in planning both bench and ridge terraces, especially if the area is to be planted to orchards. Although it is not always possible to lay out terraces on a map and later accurately follow this location in the field, the map gives one a bird's-eye view of the entire scheme such as is often very difficult to obtain otherwise.

The vertical distance between terraces in orchard land is determined more by the desired horizontal spacing between tree rows than by the slope of the land. Each tree row is on a separate terrace. About 20 feet is considered the most ideal row spacing for citrus trees in southern California, but of course uniform spacing is impossible when contour or terrace planting is used. Terraces, measured between outside edges, may be spaced 20 feet apart along some line having the average slope of the field. Where the slope is steeper the terraces become closer together, and where it is flatter the terraces are farther apart. Only one row of trees is planted on a terrace. When terraces get closer together than about 12 or 14 feet, they are usually discontinued, forming stub rows, and when they become farther apart than about 33 to 35 feet another terrace is inserted, called a fill row. In irrigated orchards it is considered more difficult to irrigate added or fill rows (rows which "point in") than to irrigate stub rows (rows which "point out"). For this reason the best practice is to locate the pipeline carrying the irrigation supply up the centre of the flattest slope, using this line also as the centre or beginning of the terraces. The terraces usually slope both ways from this point. This then makes it possible to have the greatest number of terraces starting at the point where they can be most easily irrigated. This type of planting causes the lower ends of the terraces to be in the hollows rather than on the ridges.

In contour-planted orchards, with or without terraces, the common practice is to so space the trees in the rows that the cross rows are straight. The only advantage of this is to give such orchards the appearance of being planted in straight rows when viewed from the roads and highways.

Huberty and Brown have described in considerable detail methods of laying out orchards for irrigation by contour furrows, and the reader is referred to their circular for this information.

After the bench terrace has been staked out, with the proper slope terrace interval, and other details, a strip of land from 8 to 15 feet wide, according to the slope lying immediately above the line stakes, is ploughed. The loosened soil is then pushed over along the line of stakes with a scraper, or preferably, a tool of the road-grader type. This process is repeated until the terrace has assumed the desired form. It is not necessary to provide a level tread of cross-section to bench terraces, but the nearer this is approached the better they function as a means of erosion control.

The risers are usually left undisturbed and uncultivated. When the land is not very steep, no attempt is made to move soil out toward the edge of the terrace before planting, the actual soil movement being confined to that which takes place under normal cultivation. Cultivation should always be such that it will throw the soil outward, tending to flatten the tread and steepen the riser.

With few exceptions, most of which are devoted to ornamental landscaping, bench terraces in California are used for orchards.

Ridge Terraces.—The ridge terraces, although not yet extensively used in this State has a much wider field of adaptation than the bench terrace and should become a common sight on more gently sloping hillsides. There are two types of ridge terraces, the broad-base and the narrow-base, and these may be either sloping in the direction of the terrace or level. The broad-base *level* ridge terrace is considered the most ideal of all terraces; it is intended to conserve all of the water, is readily crossed with tillage tools, and is the most easily constructed; but it has been found to be less well adapted to areas of heavy rainfall than the broad-base *sloping* ridge terrace. This terrace is often referred to in literature as the Mangum terrace, having been named after its originator. It may be used on slopes up to about 20 per cent. but it is best adapted to slopes under 10 per cent.

There is no great difference, except that of width of base, between broad-base and the narrow-base terraces, and to avoid unnecessary repetition the following description will be confined largely to the broad-base sloping terrace. The ridge is from 18 inches to 24 inches high and the base from 30 to 40 ft. wide. The narrow-base terrace is about the same height, but has a base of 15 feet in width.

Under average conditions, the sloping terrace should have a fall in the direction of the terrace of about 4 inches in the first 200 feet of its length and one inch additional for each of 200 feet of length. These figures may be modified somewhat by the nature of the soil, the steepness of the cross slope, and the amount of rainfall. Experience in any particular locality will be the best guide in regard to these features. The vertical interval between terraces will vary also with the slope, rainfall, and soils. Probably the best way to determine this is to observe the distance both vertical and horizontal through which water must travel, under the conditions at hand, before it begins to erode seriously. Observations should be made just below the crest of the hill to be terraced. For example, let us assume that at 5 feet (vertically) below the crest of the hill, erosion is readily apparent. This then should constitute a working figure, and the terraces should be about 5 feet apart vertically. (Under some conditions this interval may be as low as 3 feet or as high as 10 feet).

The high, or starting, point in the terraces for any given field should be along some line, either one edge of the field, a ridge or a hollow near the centre of the field, or some other feature which will govern the location of the terrace outlets. On land which is irrigated it would be convenient to have the high point of terraces located on ridges as is done with bench terraces in some localities. For fields up to 800 or 1,200 feet in width one edge of the field is a good starting point provided there is an outlet available at the other edge. If there is a hollow or depression near the centre of the field, then the terraces should begin on either side sloping toward the depression, or if there is a ridge in the centre of the field, the terraces may slope both ways toward the sides of the field. Short terraces 600 feet or less in length are better, than long ones, and only on rare occasions should they exceed 1,500 feet in length.

Assuming that the terrace interval is 5 feet and that the starting or high-point line has been determined, the next thing to do is to set a stake marking the point at which the topmost terrace begins. Each terrace should be staked for its entire length, one or both ways from the starting point as the case may be, by setting pegs at intervals of 50 feet. A "round-trip" furrow should then be ploughed following the line of pegs and the earth should be thrown up against the pegs from both sides. This forms the centre line of the terrace. Sharp bends and unusually crooked terraces should be avoided, if possible, by rounding off the corners at the time the first furrow is ploughed. The next step is to drop down 5 feet below the starting point and set the second line of stakes in the same manner as the first. This line is also established by ploughing a furrow around the stakes. This process is repeated step by step to the bottom of the hill.

The top terrace should always be laid out and also constructed first, since it is this one that, to a large degree determines the success of the entire project. If for any reason the top terrace fails, the lower terraces are almost certain to fail also.

The reason for staking out and ploughing around the pegs for each terrace before the next lower one is located is that often some condition may be discovered along the line which will make it advisable to increase or decrease the interval or the grade in one or more of the succeeding terraces. Under such circumstances, if the beginning point of each terrace had been located before fully staking out any of them from the work on all succeeding locations would have to be done over.

When the terraces are all located, the construction of the top one is begun by ploughing a strip about 8 or 10 feet wide on either side of the centre line. The ploughed soil is then scraped toward the centre with a terrace machine, road grader, or similar tool. This procedure is repeated, with each successive ploughing extending a little further from the centre line of the terrace, until a ridge 20 to 24 inches in height with a base 30 to 40 feet wide is formed. Not infrequently most of the soil making up the terraces is taken from the upper side with the result that the uphill side of the terrace has a somewhat flatter slope than the downhill side. On steep slopes this is unavoidable.

It is better not to plough too deeply in loosening up soil for the terrace so that the terrace channel, or area from which the soil is taken, will be broad and shallow rather than narrow and deep.

Care should be taken to see that there are no low places in the terrace which are likely to be overtopped when the channel contains water. Such places should be filled in with a shovel, if necessary.

Where a terrace crosses a gully particular attention should be given not only to the height of the terrace but also to its strength and compactness, because these places are likely to be points of weakness. The completed Mangum or broad-base should be an embankment high enough to prevent water from flowing over the top, have a broad shallow channel immediately, above it on a grade which will carry away any water which collects at a velocity which will not erode, and yet the whole area should be available for cropping without undue interference with cultural operations.

Narrow-base terraces are laid out and constructed in a manner similar to the type just described. The rise check border as used in the Sacramento Valley and elsewhere is vertically a narrow-base ridge terrace. Although well adapted to flat slopes, the narrow-base terrace has been used on slopes as great as 60 per cent.

The cultivation and planting of terraced land may be carried on as if the terrace were not there; in other words, crops may be planted in straight rows running in any direction that the planter desires. It is becoming more and more the custom, however, to consider the strips between contours as farm units and to plant, cultivate, and harvest each strip separately. For row crops the first row follows the top of a terrace and the return row follows the top of the next terrace, with succeeding rows parallel until the centre of the terrace unit is reached. If any additional space remains it is filled in with "stub" or "fill" rows as the case may be. As in the case of contour planting, this result in crooked rows and occasional short or stub rows, but it cannot be avoided.

Terrace Outlets.—The terrace outlet is almost as important as the terrace itself; for it must be capable of discharging all of the water which drains from the terrace channel without creating a gully or otherwise becoming a nuisance.

The outlet may be an open channel or a closed drain leading down the slope, or it may simply be a means of spreading the water on to adjoining land in such a way that no damage will result. The open channel should be lined with concrete, stone, or other material to prevent washing, or if the slope is not too steep, may be planted to some dense-growing permanent vegetation. The covered or tiled drain is the safest outlet. A line of tile is laid directly down the slope through the low point of the terraces or at their end, and an inlet is provided at each terrace channel through which water may enter the line. The outlet, whether tile or open drain, must have sufficient capacity to carry the discharge from any rain which is likely to occur. Where terraced fields or orchards occupy only the lower slopes of hillsides, and the upper slopes are either uncultivated

or are owned by persons not interested in erosion control, some provision must be made to care for surface run-off from this area. A cutoff ditch will be satisfactory if it is properly constructed, but it must be of sufficient size to carry all of the water which will drain into it and must not have a slope so great that it will erode.

Soil-saving Dams.—Considerable attention has been given to the control of gullies, and various devices have been employed both to prevent further erosion and to reclaim them. Several of the Agricultural Experiment Stations, as well as the United States Department of Agriculture, have publications on this subject.

A dam placed across a gully will cause a deposition of the larger and heavier particles of transported matter. Often when there is a large amount of this material the area behind the dam to the elevation of its crest, will be filled very rapidly. This will usually be sufficient to prevent further washing, but if it is desired to fill the gully, the dam must be gradually raised until its crest is even with the ground surface. Earth, brush, lumber, stones, poles, or concrete may be used for the construction of this dam. With earth dams the water, after it has dropped its load of sediment, must be diverted around or through the dam in such a way that it will not wash it out. With brush dams the water passes through, while with dams of stone or concrete the water may be allowed to pass over. Sometimes the bottom and sides of a gully may be planted to trees or even grasses, which will hold the soil against further washing. A combination of checked dams and planting has proved successful in retarding erosion in gullies.

Soil-saving dams in large or deep gullies should be considered as engineering structures, and farmers without engineering knowledge should not attempt their construction without assistance.

TEA GROWING IN NYASALAND

I feel a good deal of diffidence in addressing today a body of experienced planters, as I have only, as you well know, been in the tea areas of Nyasaland a little more than a fortnight. But I have had an unequalled opportunity, during that time, to see every corner of the districts now growing tea and have visited a very large proportion of the estates. These have convinced me of what I was not quite certain before, namely that you have here, both in Mlanje and Cholo, conditions both of climate and soil which are admirably suited for tea cultivation, and I do not see any reason why not only tea should be grown well but also why a yield should not be obtained which will compare very well with that obtained under similar conditions of elevation in the tea districts of other parts of the world. Before coming here, I was not at all certain what the prospects at least of the Cholo area were likely to be, but, though the rainfall there is less than that usually considered necessary for tea, yet the peculiar conditions which prevail at times in the cold season seem to me to neutralise the deficiencies due to a smaller rainfall.

But one thing I must say at once. I do not see anywhere much sign of a capacity to produce really fine and flavoury teas. No doubt, you can do much better in the matter of quality than has been the custom in the past, if you go in for fine, and more particularly for close plucking, and for other methods, which I shall speak of later, but I do not think you are likely to do more than secure a medium tea. It is well to work for the latter, and, in the newer gardens at any rate, I have a belief that you can reach it.

The chief characteristic of your climate, as well in Mlanje as in Cholo, is the occurrence of the dry and hot months from September to November, and this feature of your climate should, I believe, be the principal factor in determining many of the special methods which you should adopt in tea production in these areas. I have heard too much during my short stay in your districts as to whether Ceylon or Indian methods should be used in tea cultivation in Nyasaland. The fact is that, with your conditions which are not similar to those in either of the countries named, you will have to *adapt* the methods very much to your own conditions, and it may be of advantage if I indicate some of the directions in which such modifications should be made.

The undoubted truth of the statement that your conditions differ considerably from almost all districts where commercial tea has been grown in the past makes it the more important that experimental work on various phases of tea production should be done in Nyasaland itself. Hence I have welcomed very greatly the scheme for the establishment of a tea experimental station in your own areas. I have, in fact, heard with very great alarm that the scheme may have to be postponed for financial reasons.

* From the Department of Agriculture, Bulletin No. 4 (New Series) Nyasaland Protectorate.—A lecture delivered before the tea planters of Nyasaland on July 19th, 1932, by H. H. Mann, D.Sc., F.I.C.

I hope that this will not prove to be the case. I have seen the proposed site and it seems very suitable, and I trust that its establishment may not be long delayed. If it is delayed, however, I feel that a great deal of experimental work can be done on existing estates if a scientific officer like Mr. Leach is allowed to remain in the areas and be available for tea research work under Nyasaland conditions.

The definite winter and the hot weather, which is also dry, and its effects on the tea plant must dominate, I think, the special methods to be used in these areas. I say this because, while the cold weather gives a very definite annual check to growth, this check is very much emphasised by the following hot and dry period. Thus you have here something quite different from the continuous growth which is so characteristic of the more tropical tea-growing areas. This leads to the very rapid hardening up of the growing wood on the tea bushes, and wood two years old here is a very different material from that found at the same age in Ceylon. This will affect to a great extent the treatment of young plants, the methods and the time of pruning, the question as to how long tea can be left unpruned, and the methods of plucking. Not only this, but the protection of the land and the tea bushes from the hot winds and dry conditions in the months from September to November must be an important factor which will determine the question of trees among the tea, the use of windbelts, the value of bush plants in the tea areas, and the time and methods of green manuring.

The soil of the Mlanje and Cholo tea areas is not rich, though it appears admirably suitable for tea. The root system of the tea bush, when grown under ideal conditions, consists of a deep taproot which will go down for several feet and a number of laterals which arise from between four and six inches deep in the soil and which bear the greater part of the feeding root system. The taproot assures the water supply of the bush; the laterals and their feeding rootlets form the source from which the food supply is chiefly drawn. The position of the laterals leads to a possibility of continuous cultivation to a depth of four inches or more without doing serious damage to the root system, and if the taproot gets the chance of proper development the tea plants should be able to resist quite a long period of drought without serious damage, provided too great a call on the water supply is not made by a large unpruned leafy bush through the dry hot season. The soil in Mlanje and Cholo is such as to lead almost always to almost an ideal root development. The subsoils, except in a very few cases where tea has been planted in *dambo* soils, are such as to permit of a deep taproot while the character of the surface soil allows a proper lateral root development also.

But this ideal tea soil has the disadvantage of being easily eroded and lost from the surface. The result is that in many of the older estates a good deal of soil has been lost in this way. Now, however, I am glad to say that the lesson seems to have been learned, and there are very few gardens where precautions have not been taken against wash of soil. In fact, some of the work in this direction in some of the new gardens in Cholo is about the best anti-erosion work that I have ever seen. In any future extensions, I would urge that all the resources of contour planting, contour drains with bunds above them, cover crops on the faces of terraces and possibly among the tea itself, the use of trees to mitigate the force

of the heavy deluges of rain so often occur, etc., etc. should be used to prevent estates from losing the surface soil which is their most precious possession and whose loss has been of untold injury on many an estate in both India and Ceylon.

Methods of terracing and contour draining have been dealt with in previous lectures before this Association, and I do not propose to go further with them to-day. But I do want to say something about several of the other methods mentioned above. I note that the controversy regarding the usefulness of shade trees is still going on here. As regards that matter, I would only say that all the evidence available seems to indicate that *slight* shade by suitable shade trees does not affect unfavourably the production of tea, either as regards yield or quality. In fact, the very best lot of tea I ever saw on the plains of India was produced from a young garden which was at that time almost completely covered with a very light shade of *Albizzia stipulata*. But the object of suitably chosen trees is not primarily the shade which they give. It is rather the protection which they afford from the washing effect of heavy deluges of rain, the effect they have in reducing evaporation from the land in periods of drought, and perhaps more than all, their effect in manuring the soil so far as increase of nitrogen is concerned. In a very recent paper, Mr. Cooper, one of the most reliable workers in the scientific department of the Indian Tea Association, has held that a proper cover of *Albizzia* trees gives the equivalent every year of thirty pounds of nitrogen per acre. I should not myself have put the amount so high as this, but the figure is sufficient to show what a great help in manuring such trees can be. The most suitable trees in this area, so far as at present known, are various species of *Albizzia*. My old friend *Albizzia stipulata* seems to flourish well here; *Albizzia moluccana* from Ceylon, which has a slightly heavier shade, also does well, and there is a local species, *Albizzia fastigiata*, the *chikwani*, which seems to be also very good. People seem to have been very frightened of these trees as possibly encouraging root disease, and I suppose there is some danger, but I think that if they are not allowed to grow too long, being replaced by young ones every ten to twelve years, this danger is not sufficiently great to prevent the use of these trees in tea planting.

The use of bush plants among tea has made very great progress since the use of the *dadap* was introduced in Ceylon and *boga medelloa*, known to you as *bogo*, was first used in Assam more than thirty years ago. The latter is apparently one of the most valuable plants here in Nyasaland as a short-range wind protection, as a protector against erosion, when planted above contour trenches on slopes, and as a plant for regular lopping in among the tea. For the latter two purposes it is however advisable to lop severely, so that it does not become too great a drain on the soil water during the dry season. If this is done, I do not think it will be found to injure the adjoining tea as it has apparently done in some cases where it has been left unlopped. This plant is better than the local "fish poison" which is otherwise very similar. For similar purposes, the *nandolo* or pigeon pea is also very suitable and may prove even better than the *bogo*. Neither of them should, however, be left in the ground more than two years, and should then be removed and planted in other places.

Another element in protecting and improving the soil is the use of definite cover crops, which are allowed to remain on the ground. Two of these promised to be useful and there are probably many more which are only waiting to be discovered in the country. One of the two is *Indigofera endecaphylla*, which has been imported from Ceylon, and the other is a local *Desmodium*, which I have seen in use at Lauderdale Estate. Both of these established themselves very quickly, seem from my observations in the field, to feed in a different stratum from that in which the chief part of the tea roots is found, seem to shade the ground in a very valuable manner, and finally appear able to smother a certain amount of the weeds found in a tea garden. They also will allow a good deal of cultivation without being killed as they will again root themselves if interfered with. But in using them it must always be remembered that they can only be used profitably in a fairly clean garden. Specially, it is important to note that certain weeds, especially all forms of grass, must be got rid of, whether this interferes with the cover crop or not. Tea and grass will not flourish together and the grass generally spoils the tea.

I am glad to see that the use of green manuring crops is generally well understood and that they are largely used. The actual species which serve you best can only be known by experience in any particular area. But there are some general points in connection with their use which are worth repeating. A green manure crop should be grown while the amount of moisture in the soil is increasing and not when it is decreasing so that the most favourable time will be the beginning of the rainy season. Again, the crop should not be on the ground, in yielding tea at any rate, longer than can be avoided. Six weeks or two months is the maximum, and then it should be hoed in whether it has reached the flowering stage or not. I have always found that, while on the ground, a green crop tended to reduce the leaf yield of the tea among which it is sown, though this was fully made up after it was buried.

Apart from green manuring, I think that the use of other manures will have to be much greater than in the past. There is no evidence that such manures injure the quality of the tea, provided the bushes are not allowed to run away, and they certainly will increase the crop. I think that the use of cattle manure is not as general as it might be, and it would be more valuable if it were kept under cover from both sun and rain. Apart from this, I am of opinion that the most important element of manuring with you will be nitrogen, and this in the most concentrated form possible, owing largely to the very heavy railway freight you have to pay. I would very particularly recommend the use of sulphate of ammonia to you, as this will serve the combined purpose of supplying a very concentrated form of nitrogenous manure and the sulphur which has been proved by Storey and Leach to be the specific remedy for tea yellows. I do not see much evidence that potash will be normally required at an early stage in your soils, and I would be doubtful whether there is any necessity for lime in the near future. As regards the use of phosphates, I have seen no benefit from them, but, at the same time, I am almost sure that they will be wanted in most of your areas either now or before very long.

Now I may return to consider the planting methods in vogue and make suggestions with regard to them. I am certain that the older gardens were mostly planted considerably too wide, many of the older places containing plants at five feet by five feet on the square. There has been a tendency, which I think is right, everywhere in recent years to plant closer than was formerly the case, and I would not think that any planting could be justified now which had plants of Indian *jât* wider than 4½ by 4½ feet triangular or with local *jât* wider than 4 by 4 feet triangular. It must be remembered that it is not the area of the ground planted but the area of yielding surface of the tea bush that matters. And it is very difficult, with correct pruning, to get the plants to cover the ground with yielding surface if they are wider apart than I have stated.

Again, I would urge that wherever possible, good Indian *jât* should be used and not the local mixture which always makes it so very difficult to deal with the garden later. Up to now, the high cost of Indian seed has been a great hindrance to its use, but now there are available, from local sources, seeds which are almost pure acclimatised Indian seed and I should be very pleased if this or fresh seed from India could be used in all cases. There is one reason against this, namely that the local seed gives more hardy and vigorous plants, but this only means that greater care must be given to the gardens in their youth and this is desirable in any case. The Indian *jât* has two very great advantages. It will give a considerably greater yield per acre when the plants are mature. I should put the standard yield of a good tea area, in full bearing, in the case of Indian *jât*, at 750 pounds of made tea per acre, and in the case of local *jât* tea at 600 pounds made tea per acre in your area. This is an important difference, and cannot be ignored in putting out a new garden. Then, again, it costs considerably less to pluck a well-grown Indian tea garden than an equally well-grown garden planted with local *jât*. How much is the difference in this case I do not know, but I am certain that it is very appreciable. I hope, in fact, that we have seen the last of the use of local *jât* in planting out new areas because the seed is cheaper, especially now when locally grown Indian seed at reasonable rates has become available.

As to the method of planting, I would not care to judge as to the relative advantage of planting seed at stake, young seedlings up to nine months old planted with the earth round them, year old seedlings, or stump planting with seedlings two years old. My own predilection is in favour, even in your conditions, of planting nine months old seedlings with their original earth round them. This has been called "ball-planting" but I do not like the term, for it suggests that the earth is pressed into a ball round the roots, which is very fatal. But this method gives the chance of giving careful nursery attention to the young plants and yet reduces the shock of transplanting to the minimum. But, whatever method is used, I would urge that planting should be more careful than has apparently been the case in the past. I seem to have seen very few places with less than ten per cent. of vacancies after the first year, and many with far more than this. The Indian standard is five per cent. and I know places where no planting bonus is paid if the gaps exceed this proportion. I fear that very little planting bonus would be paid if this was the standard in Nyasaland!

The method which should be adopted is again dominated by the fact of the drought in September to November each year. It is little use to say that a system of planting which is successful where there is continuous growth should be used here and be equally successful. Unless plants are really established with a taproot or equivalent roots going to a considerable depth before the drought comes, the chances are that a newly-planted plant will either die or always remain as a poor and useless bush. This means very careful work, whatever method is adopted, and I would urge that nothing should interfere with this. If you can get a practically complete stand of plants at the first attempt, it will mean far less expense later, the area will be more easily treated in pruning the young plants, the later pruning will be more even, and the yield will, for a number of years, be better. I specially insist on this point for it is one in which your districts are distinctly backward and unsatisfactory.

After tea has been planted, and is established, what treatment should be given to it? Now, there are two or three things which have especially to be considered in deciding on what is to be done and how to do it. It is clear that we want no unnecessary wood in the bushes, or in other words we do not want a single stemmed plant if this can be avoided, for every bit of unnecessary stem means that the plant has to force its sap through a length that is of no use and reduces the energy of growth of the leaf. In the second place, we want to get a bush with a large surface for plucking at as early a stage as possible consistent with a healthy bush. Thirdly, the framework of the bush should be such that future treatment will not have to destroy it for as long a period as possible. And, lastly, we do not want to leave bare surfaces of wood in the early pruning which will be places of entry for white ants or fungi, more than is absolutely necessary.

The primary pruning should therefore be done at as low a point as possible—not more than four inches above the ground if possible—and at as early a stage as possible so that the young wood will be more likely to form a callus and so protect the cut surface from injury by the causes mentioned. After this, the next growth should be left of sufficient length to provide for later heavy pruning without destroying the framework of the bushes. This means that the second pruning will be about 14 inches above ground in the case of Indian *jâts* or a little lower in the case of local *jâts*. After this, pruning upward can be continued for several years, before it is at all necessary to come back on to old wood.

I know this method is rather different from that now usually followed, where tea is allowed to stand without pruning till it is six or seven feet high and the wood two or even three years old. My objections to this are two. The first is that in the period of drought a young plant so treated will very often lose its leaves, owing to lack of moisture, and so throw a strain on the plant and cause the very rapid hardening up of the wood. The second reason is that, when the plant is cut down after being so left, the cut very rarely heals and tends to become the point of entry of white ants. I have seen this going on in many cases during my stay in the districts. These evils would be largely avoided by pruning down at an earlier age, while the yielding stage of the bushes would probably be reached one year earlier. The objections to the method I suggest are, on the one hand, that the taproot does not get as great an opportunity of growing

downward if the plant is pruned down earlier, and on the other, that the plant, if cut down when the wood is only one year old, is liable to grow away again as a single stem and to refuse to bush out from the base as we wish it to do. As regards the first of these objections, I am inclined to think that its importance has been exaggerated, and as regards the second, I may say that there will be a proportion of the bushes in any case which will refuse to bush out at the first cutting, even if the pruning is done at a later stage. My experience is that there is at least as good chance of getting a proper bush if the plant is cut down on one year old wood as if it is cut down later.

The second stage of the pruning I suggest is important. After the plant has been pruned down and has thrown out new shoots from the base of the original stem, these later should grow with great vigour, if the plant is really in good order. In fact, at this stage the growth should be more vigorous than at any other stage of the tea plant's life, and it will not have to undergo the strain of plucking through this season. The wood formed should therefore be strong, thick, and vigorous, and it should be possible at this stage to leave a greater length of wood than at almost any later stage. In fact, the wood now formed should act as the permanent framework of the bush, should provide straight wood through which for many years to come the sap can flow without hindrance, and will furnish the wood on which future heavy pruning can be done without destroying the framework of the bush. If, as is sometimes done here, the wood formed at this stage is cut so as to leave only a very short length the immediate result will be that the following year's growth will certainly be somewhat more vigorous than in the plan which I advocate, but when heavy pruning has to be done, as will certainly be the case after a few years, it will not be possible to cut back on to straight wood without joints in it, without destroying the framework of the bushes,—a thing to be avoided as long as is in any way possible.

I have insisted on these matters of the early treatment of the tea bushes at some length, because I feel that considerable injury to the permanence and general high-yielding power of the Nyasaland tea estates has been done on account of incorrect pruning in the early stages of the life of the tea plants, and it is important that in the new estates these mistakes should not be repeated. After the bush has been made in accordance with the principles that I have tried to suggest, then upward pruning can be continued till the yield begins to show a falling off, when cutting back will have to be undertaken. The length of new wood to be left in upward light pruning should not be more than two inches, and may often be less than this. The new growth will always be more vigorous if the wood left is short, provided that there are dormant buds in the part left which can form the new growth.

At this stage, I may say a few words about the question of the necessity of annual pruning in your areas, or the possibility of having a two or even a three-year pruning cycle. On present evidence, I am inclined to think that there will be danger in normally leaving tea unpruned and so having a two-year pruning cycle, but I am not sure on the point. In an area where there is such a decided check to growth as you have each year, leading to very rapid hardening up of the wood, I fear that the cutting of two-year old wood which a two-year cycle involves will lead to the

production of snags of dead wood in the bushes and hence to white ant and other similar damage. Then, again, the strain on a bush covered with a full year's growth of leaf during the hot dry weather of October and November is very great. But they be compensating advantages on the other side and the matter is one which I should hope to see the tea experimental station, when it is established, take up as one of the special matters of study.

There is one other matter in connection with pruning about which I feel I must say a word or two, namely, that of the effort which is often made to retain a wide bush at any cost. Now, we all know that it is the *yielding area* of tea bush surface that determines the tea crop, and hence it appears at the first sight that the wider we can make our bush the better for the yield. And this will be the case, provided that the bush surface is yielding equally well all over. But, in fact, the surface of a tea bush never does yield equally well all over, and it will almost always be found that the centre of the bush will yield far more per square foot of surface than the parts near the sides. You can check this for yourselves on almost any area of yielding tea at the end of the season by cutting out a branch with the whole of the year's growth from a tea bush, respectively from near the centre of a bush and from near the side. If, on such a branch, you count the number of generations of shoots during the season, you will find about six or possibly seven generations of shoots near the centre of the bush on good yielding tea and only four or possibly five from a branch taken near the outside. In bushes pruned for width only, I have sometimes, here in Nyasaland, found the number of generations of shoots near the outside of bushes as low as two in the season, and it is thus obvious that in such a case the sides are yielding very little at all, while they are taking some of the strength of the bushes and so preventing the centres doing all they are capable of doing. I would strongly urge that, while every effort should be made to get bushes as wide as possible, provided that the outer portions are effectively yielding, it is no use leaving sides which are composed only of thin whippy shoots which can only lead to *banjhi* growth, and whose presence will only hinder the strong shoots nearer the centre from producing their maximum yield.

The whole study of pruning is one of great importance, to which far too little attention has been hitherto given in Nyasaland and it is one whose details, when fully worked out may, in the end, be substantially different from what has become the practice in either India or Ceylon. The same may be also said about the methods of plucking which already differ very profoundly in the other tea countries of the world. I have not time, however, today to discuss in detail the various methods adopted elsewhere and their applicability to the conditions in Nyasaland. But there is one aspect of tea plucking which almost demands attention, because I do not think you are getting nearly the full yield from the bushes owing to mistakes in plucking particularly in the middle and latter parts of the season.

There are, in fact, two methods of increasing the yield of tea. The first of these is by plucking coarse, that is to say, by plucking three leaves and a bud instead of the normal two and a bud which is considered normal all over the tea world. This method of increasing the yield is, however, universally recognised as leading to lower quality in the tea produced. Hence, while it may be justified when quantity, without regard for value,

is the policy of any estate yet it is not by any means usually a satisfactory way of increasing the amount of tea produced by an estate. On the other hand, if, while strictly plucking two leaves and a bud this leaf can be taken as soon as possible after it is formed, it may be possible to increase the yield without lowering the quality of the tea at all. In order to do this, however, it is essential that, before such close plucking as this indicates is done, enough leaf should be grown on each shoot of the bush to give a basis for rapid and constant development of new shoots during the remainder of the season. If this is done, I am confident that, still, you will be able to pluck much closer during the latter part of your season than has been the habit in the past, and so, without resorting to coarse plucking you will be able to increase substantially the yield of your tea in each season.

The lines of action would appear to be as follows. On an ordinary upward-pruned bush, tipping would be usually undertaken when the shoots in the centre of the bushes carry about five leaves and a bud. Two and a bud would be taken, leaving three leaves below the tipping point. When such plucking of primary shoots is complete, which will take probably two or three rounds of plucking, the second generation of tea shoots will be ready for plucking. These will be plucked strictly to two leaves and a bud, leaving one leaf on each shoot below the plucking point in addition to the *fish* or *janum* leaf. The plucking of these shoots should be made at such frequent intervals as not to allow more than a very small proportion of the shoots to grow longer than this, and it is of much importance that the bush should not run away at this time of year. This plucking of second flush shoots should be complete some time in December or in January. After this stage, the bushes will be growing very vigorously, and there will be a great tendency to run away. But if, at and from this stage, you can pluck the further leaf, down to the *janum* leaf, as soon as each shoot has formed the required two leaves and a bud, you will, I think, get a larger amount of leaf in the season without injury to the bushes and while plucking strictly two leaves and a bud throughout the season. Not only will a larger yield be obtained, but also the tea made will probably be better in quality than that usually obtained, for it is I think generally recognised that closed-plucked leaf, in the sense here indicated, will give better quality tea than if plucked at the end of runaway shoots.

For this method, however, one thing is essential. There must be plenty of plucking labour in the busy months of the plucking season, for if the leaf is not to runaway it will be necessary that every block of tea shall be plucked, in the height of the season, at intervals not greater than seven days, and possibly even more quickly than this. From a study of many of the bushes in the Mlanje area, I feel that it is at this time of the year that both yield and quality are lost, as there is much evidence of "running away". Such running away not only causes the immediate loss of leaf but tends to make the shoots become *banjhi*, and so leads to an early close of the season. I feel, in fact, that if you could pluck closely in the sense I have described, after the early part of January, you would get more tea, better tea and a longer season than is now the case.

I need only say a word or two regarding the pests and blights of tea in Nyasaland. On the whole I find you are wonderfully free from serious diseases and enemies of the tea bush, especially since the very serious tea yellows has been investigated and a very simple method of dealing with the disease laid down by Storey and Leach. Apart from this disease, the only two serious troubles in the way of disease that I have seen are on the one hand the well-known mosquito blight of tea (*Helopeltis*) and the various root diseases, the most serious of those prevalent here being that caused by *Armillaria*. This latter is one of a group which can be very largely eliminated in a new garden by thorough stumping of the land before planting, and by the avoidance of certain trees in the tea later on. There is apparently some danger of this disease being caused by stumps of the *chikwani* tree in old tea, but if these trees are not allowed to grow among the tea for more than about ten years before they are cut down and replaced by young ones, I do not think the danger is very great. I understand that some doubt has been expressed as to the advisability of growing *bogo* or even *nandolo* among tea, they being possibly hosts of root fungi, but if they are not allowed to stay more than two years before removal, I do not think there is any evidence of their being likely to cause root disease.

With regard to *Helopeltis* or mosquito blight of tea, I have seen it everywhere, but there is very little evidence of any serious damage to the flush or of any attack with one-tenth part of the damage that is often seen in Indian tea gardens from the allied Indian species in north-east India. There is one effect which it apparently causes as has been shown by Mr. Leach quite recently, which may be serious for it appears to be the primary cause of what has been called branch canker of tea though it is really not a canker in the technical sense at all. The only conditions in which this is likely to be a serious matter are those of heavy-pruned tea, where the new shoots, which have to form the framework of the bushes resulting from the heavy pruning, may be attacked, and, if this is the case, it may seriously affect the future of such bushes. I have seen this actually happen, to a quite serious extent, in one of the best young gardens in the Mlanje area. In this case I feel that the employment of a gang of trained children in such heavy-pruned tea to collect the insect will probably meet the situation. They should be employed from the time the new shoots break away from the heavy pruning.

Before referring to the question of tea manufacture, may I say a word on two about the quality of tea in general? The quality of tea, that is to say, the amount of the flavour, pungency and body in the liquor infused from tea, is one of the most elusive characters in connection with the production of our product. It was at one time thought that tea obtained from a high elevation would almost certainly have the most desirable qualities as is really the case with tea produced in the mountainous districts of Darjeeling and Ceylon. But there are some areas where all the tea is grown at a very high elevation, where high standard of flavour, etc. is not obtained. Some people have connected high quality with slow growth, but, again, this is not necessarily the case, for I have known very slow growth produce the most ordinary of tea. Some authorities have stated that highly manured tea is not likely to give high quality, but the latest

accounts do not own any connection between manuring and quality, provided the tea is equally well plucked when ready. There is no doubt that methods of pruning and plucking do have some effect, and that close plucking is more likely to give high quality than plucking from a runaway flush. My own idea has long been that the soil is the primary factor and that it is only by suitably treating the soil that the quality of tea from any particular area can be carried into a higher class. But when you ask me to define how the soil should be treated so as to produce the highest quality, I am compelled to admit that I cannot speak with any confidence.

In Nyasaland, you have, on the whole, been producing tea which belongs to the common grades. And I must confess that I do not see much immediate hope of your getting far above that grade, except so far as it can be done by generally increasing the vitality of your bushes and then plucking strictly and closely throughout the season. By analogy with the best Indian districts, you ought to produce the best of your teas in about December (second flush tea) which should stand out in respect of strength and flavour, and at the end of the season, when the teas should be most marked in flavour. And I would suggest that you should concentrate attention in the first place, on these two periods when plucking should be most careful and manufacture most carefully controlled. Though I do not see much probability of your getting more than a medium tea, yet the difference between the value of this and what you are now getting is large enough to make a great deal of trouble well worth while.

You will notice that in these remarks about quality, I have said nothing about the effect of manufacture in connection with quality. I hold, however, that the function of manufacture is to make the very best out of the leaf that is provided by the gardens, but that in many cases there is little chance of making a high quality of tea from the leaf supplied to the factory. But it is very important that nothing should be done in the factory which will prevent the leaf giving the highest quality of tea of which it is capable. And no tea planter should be content with his product unless he is satisfied that his factory methods are such as to lead to this end.

I have not time to deal today with the defects which I have found in factory management while I have been in Nyasaland. Unfortunately I only came here at the end of the tea-making season and I have only seen manufacture as it is done at the fag end of the tea-making year. But I will say that I think you have a long way to go before most of the factories here reach the standard of manufacture that is now customary in the estates of India and Ceylon. Three tendencies have been most marked in tea manufacture in these older countries during the years while I have known them. The first is a greater and greater attention given to the most scrupulous cleanliness at every stage of the manufacture, for it is recognised that the slightest slackness in this connection means the presence of microbes in the material under treatment, and this means a lowering in the quality of the product. The second is a greater and greater attention to the preservation of a moist and almost saturated atmosphere, during the rolling and fermenting processes at any rate. And the third is the gradual introduction of more and more control of the manufacture and less and less dependence on the weather conditions outside. This control is most visible in the matter of withering, where withering lofts, most largely

in Ceylon and Java but to some extent everywhere, are now so arranged that under any weather conditions a good wither can be obtained in almost the same number of hours.

We have a good deal of leeway to make up in all these matters in Nyasaland before we are able to stand on a level with the best of the factories in India and Ceylon. Some of the advance has been due to money judiciously laid out on the best form of controlled withering lofts, or to the introduction of methods of air conditioning in the rolling and fermenting rooms. But, far more, the general advance has been the result of greater and greater care in these directions in making the very best use of the facilities that already existed in the factories. I propose to deal with how this can be done in my final report on my present visit to Nyasaland, but I am confident that the insistence which I now make on these three points will indicate what can be accomplished with additional care, even with the present equipment.

In conclusion, may I state in general terms some of the more important conclusions which I have reached as a result of my stay in the tea districts of Nyasaland? In the first place I am deeply impressed with the future possibilities of tea in the areas of Mlanje and Cholo where tea growing has been established. The conditions are favourable, and the work done, in the more recent years at any rate, has been, in a very large measure, of a first-class character. Already the cost of the tea produced per pound on the estate has been reduced almost, if not quite, as low as is the case in the most favoured regions of India and Ceylon. But I can see ahead of us a very considerable increase of yield per acre, and this will all tend to a still further reduction of local price per pound of tea. On the other hand, I must confess that while I see the possibility of a very substantial improvement in the quality of tea produced in Nyasaland, I do not see much evidence that you will convert your tea into a high-quality product. To get even the improvement of quality that I can foresee will mean the adoption of some modifications in both pruning and plucking and a good deal more control in the manufacture.

But while I can see a bright future for tea planting in Nyasaland so far as the local conditions are concerned, I am very concerned, as everyone must be who knows the situation, regarding the cost of putting the Nyasaland product on the market, owing to the very great cost of taking the tea to the coast for shipment. I have been given figures which show a cost of nearly a penny per pound between the railway station and the port. This compares with a freight from Assam to Calcutta of about 0·38 pence per pound, from Sylhet to Calcutta of about 0·23 pence per pound, and from the Dooars to Calcutta of about 0·28 pence per pound. If you were producing or were likely to produce a high-priced tea, perhaps there would be no necessity to insist on this point, but with a tea whose final sale price in London is now about sevenpence per pound, the cost is a crushing burden and makes competition difficult.

And yet I can see no reason why planters in Nyasaland should take a gloomy view of their enterprise. With a likelihood that larger yields can be obtained in the future than in the past without loss of quality, with even a possibility that better tea will be produced in the future than in the past, with the early probability of the establishment of a special experimental station to investigate the special needs of the tea industry of Nyasaland, and with, in general, increasing interest on the part of the powers-that-be, in the industry, I see no reason for a pessimistic view of the present position.

VARIATION IN CITRUS ORCHARDS*

THE variation in production and size of individual trees in citrus orchards is not a mere bogey of horticultural advisers but a fact demonstrated on each occasion of testing.

Thus Webber writing in 1925 of South African groves gives the following opinion: "Some groves, particularly those 10 years of age or older, are made up in considerable measure of trees of variable types, frequently almost or quite worthless as commercial sorts. This is particularly true of the early planted Navel groves. In many orchards of all ages there are frequently variations in size of trees and in yielding capacity, many trees existing that apparently year after year are regularly low yielders or 'boarder' trees."

Again Hodgson in urging Californian growers to take simple tree records, notes the presence in orchards of 3 types of tree, i.e., the entirely unprofitable, the self-supporting and the profitable tree. He gives analysed figures of cropping from three orchards as follows:

Orchard	1	2	3
Percentage of unprofitable trees	13·0	14·0	32·0
Percentage of self-supporting trees	19·0	32·5	42·0
Percentage of profitable trees	68·0	53·5	26·0
Total number of trees	5,736	800	1,525

It will be seen that even in an outstandingly profitable orchard such as number 1 segregation of trees into these classes shows that approximately one tree in three is either only self-supporting or is actually carried at a loss. He writes in 1923: "In the average orchard it is believed that the percentage of such trees is near 50".

Again there is the evidence of Batchelor and his co-workers to show the existence of variation. In preparation for fertilizer experiments they aimed at uniformity of material, treatment, and, as far as possible, soil. To ensure uniformity of material they adopted the following methods of propagation:

(1) The sweet orange (C. *sinensis*) stock, transplanted from seed bed to nursery in 1914, was culled and undersized trees amounting to about 15 per cent. eliminated. (2) At the time of budding in 1915 a further elimination of small sized trees was made. (3) On transplanting the budded trees in 1917 a third discarding of trees lacking vigour and size was carried out.

In budding only plump, well-formed buds from mature old wood were used, and only such twigs were used as showed blossoms formed or in process of formation on the tips of the current season's growth at the time the budwood was cut.

* From Imperial Bureau of Fruit Production, Technical Communication No. 3., November, 1932.

And yet yield and growth records taken during the twelve years of life, from planting up to the time of first application of fertilizer treatment, revealed the existence of considerable variation. Thus there was a difference of practically 109 per cent. between the lowest yielding plot, which produced an annual average of 79 lb. of oranges per tree for the 6-year period recorded, and the highest yielding plot which produced 179 lb. This variation was not considered strange by the authors in comparing areas of soil one-third mile apart. But, in addition, they also found variation in production of adjacent plots amounting to 30-40 per cent. They consider that the two groups of factors which are most persistently operative in causing the variation in production are (1) the inherent qualities of the trees due to character and vigour of rootstock and top, (2) the variability of the productivity of the soil. They comment as follows: "In spite of the variations in the growth and production of the trees of this field, it is believed that this planting is singularly uniform in comparison with the average citrus grove. This fact has been brought out in statistical studies of the variability of this and other orchards. In appearance the trees are strikingly similar."

In an earlier study on the nature and extent of the casual variability of yields of Navel and Valencia oranges and Eureka lemons under field conditions, and its bearing on the reliability of plot trials, Batchelor and Reed selected for their trials orchards uniform in treatment and appearance, and yet found considerable variability in productivity. The coefficient of variability for the yield of individual trees of these clonal varieties ranged from $29{\cdot}27 \pm 0{\cdot}69$ to $41{\cdot}23 \pm 1{\cdot}52$ per cent. Computations made on the yields of the orange trees for several consecutive years showed little annual fluctuation in their variability.

Many other workers have testified to the variations usual in citrus orchards. Thus Webber in 1920 noting the existence of variation in yield of trees of the same variety in the same orchard, planted at the same time and cultivated alike, considers it likely to be due primarily to one of the following factors:

1. Variations inherent in the buds due to different heritage.
2. Different kinds and characters of stock used.
3. The character of the union obtained in the budding and grafting.
4. Differences in environment.
5. Accident.

The influence of the stock on the variation observed is believed by him to be fundamental. He notes the normal practice to be as follows:

The stocks are grown from seed and the seedlings transplanted from seed-bed to nursery about 12 months after sowing, at which time they vary greatly in size, ranging from a few inches to 18 inches or more, this variation being always seen. In ordinary practice all of the seedlings are transplanted or at most only a few of the smaller ones are discarded.

After another 12 months those large enough are budded, there being considerable variation in the size of the seedlings, the smaller ones being budded later.

The budded trees then wait another two years and are transplanted to the grove. At this time they still vary greatly in size. Quite commonly only the largest trees in the nursery will be dug and sold, while the rest will be left for a future occasion.

The smallest trees for the smallest stocks will finally reach sufficient size and ultimately find their way into the grove. He considers that the question whether this small tree is as likely to produce a good productive orchard tree as the vigorous growing one selected previously remains unanswered.

Webber describes here an experiment in which he graded out seedlings of sour and sweet orange on transference to the nursery, discarding for inadequate size about 15 per cent. of the sweet and 25 per cent. of the sour stocks.

A further grading preceded budding, when those surviving the test were budded with 4,000 buds of Washington Navel and Valencia orange and Marsh grapefruit on the sweet stocks and 4,000 Eureka lemon buds on the sour stocks. All buds were specially selected from trees of known and uniform history for the previous five years. Throughout the rest of the time in the nursery the trees gave every appearance of good growth and comparative uniformity.

Two years later the trees were regraded, 15 per cent. being rejected as undersized, while the rest were planted out. Even so the author was able to grade those remaining into 3 lots, small, medium and large.

The Eureka lemons did not stand transplanting and the experiment with them lapsed.

Of the remainder, two and a half years after transplanting, the large intermediate and small trees were found to retain the same relative size that they had when dug in the nursery.

An examination of other possible causal factors led Webber to consider that the most important cause of difference lay in the stocks.

He says that among rootstocks in common use such as sour orange, sweet orange, grapefruit, lemon and trifoliate "It is known that there are hundreds of different variations, types or varieties within each".

In examination of a stock nursery of sour and sweet orange, Webber, Mertz and Thomas, were able to select out 16 different types of sour orange and 4 different types of sweet orange. Many more could have been selected. Two years after planting out these different types were found to be remarkably distinct from each other in character and size of growth, branching foliage and other important characters. An examination of stocks at Berkeley confirmed these findings, so that Webber remarks "There is no doubt that citrus nursery stocks as ordinarily grown are made up of a very large number of widely different types of different genetic constitution, exhibiting a wide range of characters". He recommends: "When any seedling is found to be a good stock type, it can be propagated by buds and each nurseryman can grow enough trees to supply the seeds required for his nursery use."

He then gives definite recommendations to those wishing to produce uniform citrus trees. As a preliminary necessity he urges that good stock varieties of sweet and sour orange should be found, named and grown regularly to furnish seed for the production of nursery trees. (This is actually practised in the Aegean Islands and near Milazzo in Sicily. In these localities extensive, isolated areas are devoted to the raising of sour orange seedlings for ultimate use as rootstocks in an endeavour to maintain the purity of selected strains and thereby secure some measure of uniformity.) The rest of his recommendations concern the elimination of variants by selection.

Twelve years' further work and observations in California have merely served to confirm his opinions and his recommendations remain materially unchanged. In *Hilgardia* for June, 1932, he writes: "in any lot of seedlings grown from seed of the same variety and from the same source, from 5-40 per cent. are highly variable types, which apparently differ in genetic constitution from the prevailing type and each other". The remainder are of the same general type, and are, he considers, probably of apogamic, i.e., asexual origin. He notes in great detail the evidence of variation and its causes and demonstrates the existence of very strong evidence that small seedlings and small budlings tend to produce small, low-yielding trees, and large seedlings and large budlings to produce comparatively large, high-yielding trees. The most important factor is the elimination of the variant seedlings, "that are found almost uniformly to produce weak and dwarfed orchard trees".

He considers the normal methods of elimination and makes a searching comparison from an economic standpoint of pre-budding and post-budding selection, which results much in favour of the former.

Dealing with sour and sweet orange stocks and the production of good uniform trees, he recommends the adoption of the following practice in the nursery:

Seed Bed Selection.—This should consist of a discarding of the smallest plants up to 25 per cent. of the total at the time of transplanting to the nursery, i.e., one year after sowing. This would eliminate a considerable proportion of the variant types.

Nursery Selection.—This should be made just prior to budding when the seedling has been 2 years in the nursery and has had plenty of time to show its top characters, and should consist of the elimination, irrespective of size, of any seedlings differing from the normal in any way and in addition of small seedlings up to a limit of 25-30 per cent. of the remainder "After this elimination," he writes," the entire remaining population may be budded and safely regarded as propagated on good, uniform, highly selected stocks. As the seedlings up to this time have little value, it does not entail very great financial loss."

Budling Selection.—Small and inferior budlings should be removed before digging for planting out. This elimination should be very slight, with good buds and selected stock probably not more than 1-5 per cent.

The problem of achieving uniformity in the citrus orchard has never lacked attention from Webber and it is interesting to note his experiences in South Africa.

In 1924-25 he conducted a special enquiry on the citrus industry of the Union, and as a result he recommended a serious trial of vegetative propagation methods for raising not only scions but also rootstocks.

In his report he notes the proved unsuitability for South Africa of the Seville orange as a rootstock and discusses the possibilities of the rough lemon.

He considers that the lesson to be derived from his own work and experience seems clear, namely that we cannot expect to obtain uniformly good lots of trees from ordinary, unselected seedling stocks, every individual of which differs in some character. Thus as a casual example, an examination of a group of 30 seedling rough lemon trees of about 7 years old showed 4 distinct types, strains or varieties, each of which he considers, would react somewhat differently as a stock.

In future he concludes: "We will have to select good stock strains that by experiment are known to produce uniform seedling progeny, or it will be necessary to find good stock strains and propagate budding stocks from these by some means such as layering or by cutting in order to ensure uniformity.

His search for good strains propagated asexually was successful. He found that in practically all cases layered trees seemed to possess rather an exceptional vigour and fruiting capacity. Fair comparisons were made between Valencias and Navels budded on rough lemons and others growing on their own roots from layers. In no case did the layered tree suffer by the comparison. He saw no evidence of the layered trees being rooted only on one side, nor did they appear more liable to uprooting by the wind, though he did note that they had no taproots. Sweet orange layers were indeed susceptible to collar rot, but no more so than sweet seedlings. Wherever plantings of layered trees were found they were clearly as good or better than any other trees in the grove.

The Washington Navel is in general a slow growing rather weak tree and one could understand the failure of such a variety on its own roots. Yet some forty ten-year old layered Washington Navel trees near Grahamstown were seen to be growing just as well as others budded on rough lemon. If then this does fairly well, sorts such as Valencia which are naturally vigorous, should do very well.

But the method of propagating by layering as practised in S. Africa, of which Webber gives an illustration, is not conducive to the production of a large number of rooted layers, only one tree being produced by each layered branch, nor had it been used for getting rootstocks. Despite this, Webber suggests that the use of layers or cuttings for propagating citrus stock might prove extremely valuable and he considers that experiments might profitably be made with the method of layering so successfully used for deciduous fruit trees (i.e., pinning down and covering the young shoot, which will then root at the nodes). A warning note is sounded by him in this connection. This method of propagation, however, would in general give no opportunity to effectively practise bud selection, and this is a serious drawback with unstable sporting varieties like the Washington Navel and the Valencia, and is somewhat risky with any citrus variety."

Webber was thinking here in terms of own rooted trees as a possible method of achieving uniformity. The more economic practice being, however to bud or graft varieties on to particular rootstocks, the actual problem is to achieve uniformity of production from this compound plant of rootstock and scion. Uniformity of soil and treatment are essential. As regards the rootstocks, standardization of seedling stocks by elimination of variants in the nursery has already been touched on and will be referred to again in the section on polyembryony, while details of propagation by layering cuttings, etc., will be found in the following pages together with notes on the work of bud selection of scion varieties.

POLYEMBRYONY

That variation exists within such groups as sour orange, sweet orange, trifoliate, pomelo, etc., has been shown by many workers.

Bonns, and Mertz, moreover, who made notes on the first five year's cropping of Valencia and Washington Navel orange and Eureka lemon on the above stocks, came to the following conclusions: " . . . It is evident however, that there is no ground at present for recommending any particular stock for increase yield or quality of fruit of either of the oranges or the lemon used in this experiment." They note considerable variation in cropping indeed, but this variation was not necessarily any greater between trees on different types of rootstock than between trees on the same type of rootstock. As they point out it was scarcely to be expected that evidence would be available in so short a time, but later trials, some of which are referred to in the previous section of this memorandum, show that variation still exists at a much later date than 5 years from planting, even when every effort has been made by careful selection to ensure uniformity.

Can approximate uniformity of rootstock be attained, and if so, what is the easiest method? If it can be attained without recourse to the usual methods of vegetative propagation, the problem will be much simplified. In the case of citrus the factor of polyembryony may offer a solution.

It has long been known that the seeds of certain species of citrus are polyembryonic. As early as 1719 Leeuwenhoek discovered two embryos in orange seed, but the real nature of the phenomenon as regards citrus remained unexplained until demonstrated by Strasburger in 1878.

Polyembryony, or the presence of more than one embryo within the seed may arise in various ways. In the orange it may be ascribed to a stimulus received by the cells of the nucellus, both above and below the embryo sac, even though separated from it by several cells. Strasburger found that no seeds develop without pollination and from this concluded that fertilization of the egg cell is necessary for the formation of the nucellus embryos. The experiments of Toxopeus bear this out. Toxopeus states, however, that strictly speaking his own experiments have proved only that pollination is essential and do not definitely decide the point whether actual fertilization is also necessary. The possibility remains that the stimulus may be given by the mere ingrowing of the pollen tube, though his cytological investigations strongly suggest the necessity for actual fertilization.

Neither spore nor egg cell being involved in this reproduction process, the formation of these additional embryos may in effect be regarded as a case of adventitious budding, analogous in its results to true vegetative

reproduction. It follows that on germination one seedling will be a true cross while presumably the remainder, numbering sometimes as many as ten, will differ in no way from the mother plant.

Frost found that citrus seeds varied greatly both in the number and in the size and shape of the adventitious embryos contained. He thinks there must be much competition both between themselves and between them and the fertilized embryo, and that the chances of survival to germination point must depend largely upon size, position, relative age and vigour of the two classes of embryo. In it he sees a form of developmental selection, natural selection acting within the soma of the parent (the evolutionary significance of this has been discussed by Buchholz in 1922) since genotypes inferior to the seed parent would tend to be severely handicapped by the competition of the vigorous apogamic embryos.

The economic significance of the phenomenon has not remained unobserved. Thus, if it is possible to distinguish the sexual seedling from the others in the seed bed, it would seem that nothing further should be needed to preserve a pure line of vegetatively reproduced descendants beyond the elimination of this seedling. Work by Webber, discussed by him in a paper at the Ninth International Horticultural Congress, seems to suggest that polyembryony can be turned to good account. Dealing with the variation seen in the seed bed and their persistence he writes: "The evidence seems thus to indicate that, if the variant types of seedlings (i.e., the generative offspring) were eliminated in citrus at the seed bed, the remaining seedlings, would show different sizes due to crowding and environment, but that the important inherent differences in the growth rate, if any exists, cannot be recognized at this time. It also seems to be the case that the remaining seedlings, after the variants are excluded, would show less genetic variation than would be expected in apple seedlings after excluding the marked variants, and should thus give a lower coefficient of correlation between size of nursery stock seedling and size of budded trees. "He notes incidentally that smaller correlations were obtained in his experiments than in the case of various repeated experiments with deciduous fruits.

Toxopeus, experimenting in Java with many kinds of citrus varieties, found the percentage of vegetative progeny arising from self and foreign fertilization in these varieties. Actually in the case of many hybrids the type of fertilization did not affect this percentage appreciably. Varieties examined included types of the following: C *nobilis*, C. *aurantium*, C. *grandis*, C. *aurantifolia*, C. *medica*. As regards the elimination of generative seedlings he found that there was no difficulty in picking out the offspring of complicated hybrids at a very early stage. Thus the generative offspring from such hybrids sown in December, 1928, were readily picked out in July, 1929. He states that, if negative selection of these off-type seedlings is made, 90-100 per cent. of the remaining plants will be of vegetative origin. This has also been found to be the case with two of the best stock varieties possessed by the Horticultural Extension Service in Java, namely Japanese citron (C. *nobilis* Lour. hybr.) and Citronella rough lemon. When on the other hand the mother parent is

not a hybrid and the percentage of vegetative seedlings is known by trial to be less than 90 per cent., the generative seedlings can be made distinguishable from the vegetative type by crossing with a very different father plant. For the pollen plant to be employed usefully, it should possess one or two characteristics, which in the resulting hybrid will dominate pronouncedly at an early age over those of the seed parent.

In a recent article Toxopeus describes the method of differentiating between the generative and vegetative seedlings of Japanese citron and rough lemon. As regards the latter he notes that the generative offspring amount to only 4 per cent. generally show very poor growth and are very easily distinguishable. The seeds produced 2 or 3 embryos which obstruct each other's growth very considerably. The weakest may be removed in the seed bed and the rest transplanted after developing their second leaves. In Japanese citron, where the percentage of generative offspring is much greater, 50-60, there is a greater danger of confusion, though to an observant eye the differences are obvious. To help those not conversant with the typical characters Toxopeus gives a comparative table of leaf and stem characteristics which mark the vegetative seedling, and the several characteristics which are likely to be seen in the generative seedling. Again, the generative plant is usually a weak grower.

As regards the hybrids themselves Toxopeus has found that only a very small proportion are compatible, i.e., some 28 out of 1,400. It is interesting to note that none of these 28 had pomelo as a parent. There is as yet, of course, no evidence as to the growth and cropping of citrus varieties worked on any of the compatible stocks, but at least there is hope that some, at any rate, will by field trials be proved valuable as stocks, in which case their reproduction by vegetative methods, including selection from polyembryonic seed beds, cuttings, layers, etc., might be a source of uniform rootstock material.

Webber in the current volume of the *Proceedings of the American Society for Horticultural Science* notes that apogamy, or the production of seedlings from unfertilized embryos, presents considerable difficulty to the breeder, but may be turned to good account by the nursery man, "who should thus apparently be able to obtain easily from any good stock type large batches of seedlings, which can be depended upon to be of nearly uniform genetic type and to react uniformly on the scion." Writing in 1931, he noted, however, that the percentage of apogamic embryos in certain citrus species and varieties used as stocks varies considerably. Obviously any stocks to be perpetuated by this vegetative seedling method, however desirable their other qualities, must possess the polyembryonic factor to a marked degree. The actual range of apogamy has been determined for certain varieties by different workers, and is given by Webber as follows:

Species	Range in Percentage of apogamic embryos
Sweet orange varieties, C. *sinensis*	40-95
Sour ,, ,, , C. *aurantium*	75-85
Grapefruit ,, , C. *grandis*	60-95
Mandarin orange ,, , C. *nobilis*	10-100
Lemon ,, , C. *Limonia*	10-96
Citron ,, , C. *medica*	40-50
Trifoliate orange ,, , *Poncirus trifoliata*	72

A factor of exceptional interest is the high percentage of apogamy shown by some FI hybrids of radically distinct species and the fact that such hybrids are often likely to be valuable as stocks. Thus progenies of the citronge, a hybrid of P. *trifoliata* (72 per cent. apogamic) and C *sinensis* (40-95 per cent. apogamic), have in Webber's experience always reproduced the citronge type, and may thus be considered as 100 per cent. apogamic. Among varieties which are not entirely apogamic he has found that there is a proportion of seedlings differing from the prevailing types. These variants are commonly, but not always, of comparatively small size and "almost invariably produce some degree of dwarfing in scions grown on them. The evidence available indicates that these variants apparently are seedlings produced from the normal (sexual embryos, probably mainly by self-fertilization. The roguing out of these variants from a batch of nursery seedlings before they are budded is the most important selection that can be made in the nursery. The seedlings remaining after such an elimination can be safely considered to be chiefly of apogamic origin."

Nevertheless, even among apogamic seedlings remarkable variations have been noted from time to time, the phenomenon being ascribed by Frost to chimeral conditions in the parent trees. Thus a pollen-sterile Navel orange has been known to produce apogamically, several fertile, non-Navel progeny. Again Webber's experience during the last twelve years shows that reproduction by vegetative means does not eliminate the necessity for selection in the nursery. He finds that "within comparatively homogeneous, apogamic seedling progenies of citrus the large seedlings in general produce larger budlings than the small seedlings of the same progeny and that this larger size is maintained in the orchard for at least several years. Trees on large seedling stocks during the first 8 and 10-year periods in the orchard have yielded over 19 per cent. more than comparative trees on small seedling stocks from the same apogamic progeny." He considers that though eventually the difference may disappear, it may be maintained for many years in long-lived, slow-growing perennials, such as citrus, and may be attributed to the hold-over influence of large size and vigour in the young seedlings or cuttings. Although the heritage of such plants is unlikely to be affected by the process of selection in the nursery bed, he considers such selection to be economically sound, and gives figures to support this view.

Toxopeus, summing up the possibilities offered by the polyembryony, says that it enables us in one way or another to raise in one year from a single tree a very much greater number of vegetative progeny than would be possible by methods of budding and grafting without spoiling the mother tree. Further, new varieties can be imported as seed, thus minimizing the risk of importing disease. If the seed is found satisfactory, then by observation of the number of embryos an estimate of the percentage of apogamic offspring can be made. If this is high, a single sowing will furnish a large percentage of replicas of the mother plants; if low, twinning will be necessary. (In twinning the seedling is split vertically in two, thus securing two plants instead of one.)

NOTES ON TOBACCO CULTIVATION*

CLIMATE and soil are the most important factors governing the successful cultivation of tobacco.

Extremes of temperature, uneven distribution of rainfall, lower relative humidity owing to continued bright sunshine and drying winds, tend to prevent even growth of tobacco, with the result that it is comparatively poor in texture and smoking quality. Judicious irrigation may, to some extent, alleviate the condition of uneven rainfall, but irrigation cannot be regarded as other than supplementary to natural climate.

The other essential condition for the production of good quality tobacco is suitable soil.

The most suitable soil for tobacco culture is a fine-textured, greyish-coloured sand or sandy loam, fairly deep and naturally well-drained, with a friable sandy clay subsoil. It is generally recognised that the more humus a soil contains the more suitable it is for the production of bright flue-cured tobacco of good quality, provided that the rainfall is adequate and evenly distributed.

Analyses of soils from tobacco-growing areas in Australia show that in many cases the proportion of silt and clay is too high for the production of tobacco with a good smoking aroma.

Analysis shows that 1,000 lb. of cured leaf removes 80 lb. of potash, 60 lb. of nitrogen, 40 lb. of lime, and 16 lb. of phosphoric acid from the soil. The soil, therefore, must be able to supply the plant with the elements necessary for its growth in such a form as to be most suitable for the development of good quality leaf. Using light sandy soils, it is obvious that most of the elements must be supplied artificially as fertilisers.

The food substances in the fertilisers are dissolved in soil water and absorbed by the root system of the plant, and consequently it is essential that the root system should be well developed. Good tilth and satisfactory rainfall determine the capacity of the root system.

Water is evaporated from the plant and the food substances are left behind to be used in building up plant tissues. If the atmosphere is humid, the intensity of sunlight is reduced and so is evaporation, and under these conditions the plant-food elements absorbed are used up at a normal rate. If the plant is grown in rich soil under intense light, high temperatures, and a dry atmosphere, evaporation is rapid and the accumulation of food supplies exceeds their normal use. Such leaf is likely to be coarse or tough, and to have an objectionable smoking quality.

Good tilth is necessary to ensure a good stand of plants from the first, and to ensure steady growth. Seed beds should be rich and well-drained, protected from cold winds, but exposed to sunshine. It is advantageous, and essential in some areas, to sterilize the soil by heat in order to kill weed seeds and disease-causing organisms.

* From Bulletin No. 3 Australian Tobacco Investigation.

Transplanting should be undertaken as early as weather conditions permit, the plants should be uniform in size, and, if the weather is hot, they should be protected by covering with paper hoods until they are established.

One man can satisfactorily handle only 5 acres of tobacco, and even with this area assistance will be needed at harvest and during curing.

"Topping" is the process of removing the flower-head and the small top leaves, so that on an average twelve or fourteen good leaves (not counting the bottom trashy ones) are left on the plant. The trash leaves should be removed at the same time, and this operation is known as "priming". Shortly after topping lateral shoots must be removed, and this is known as "suckering".

Usually about four weeks after topping the bottom leaves begin to mature, and this is indicated by a change of colour from dark to pale green or by yellow mottling. The more satisfactory method of harvesting for curing is that of taking individual leaves of the same stage of maturity.

Curing does not make good tobacco out of poor leaf, but, if properly done, it fixes and further develops quality already established during growth.

Flue-curing is a relatively rapid process, suitable for bright types of tobacco grown on light sandy soil. For tobacco of high nitrogen content produced on heavier soils the slower process of fire-curing is more likely to yield a good final product.

After curing the leaf is ordered (so that it may be bulked without damage), by remoistening until, when it is squeezed in the hand, there is a slight cracking in the lateral veins. It is then bulked, with the bottom layer well off the ground, covered with bags and weighted down to prevent drying. After good-coloured leaf has been bulked for about five weeks, it is ready for grading and baling.

There is a demand for a limited supply of Burley tobacco, which requires a soil reasonably rich in lime, nitrogen, potash and phosphoric acid. It should be grown fairly large, the leaves should have good body, and they should not yellow prematurely in the field. It must be air-cured on the stalk in a barn which will give protection from wind and allow regulation of the rate of colouring and drying.

From seed bed to harvest the tobacco-grower has to contend with diseases and insect pests of some kind. Downy mildew (blue mould) is the most important disease in southern areas, while damping-off and frog-eye leaf spot are worst in northern areas.

Damping-off is controlled by thoroughly sterilizing the seed bed soil by steam, burning, or drenching with formaldehyde.

Frog-eye leaf spot is being investigated: but, in the meantime, growers are recommended to avoid planting seedlings showing spots of any kind, to spray seed beds with Bordeaux mixture at intervals of from five to ten days according to weather conditions, and to remove infected sand leaves as early as possible.

In bulk the moisture content of the leaf must be kept under control, usually about 14 per cent., to avoid the development of moulds, which rapidly give a musty odour to the bulk.

During the growing season, insect pests, especially cutworms, bud-worms, etc., must be controlled by baiting or dusting.

MEETINGS, CONFERENCES, ETC.

THE COCONUT RESEARCH SCHEME (CEYLON)

BOARD OF MANAGEMENT

Minutes of the 19th meeting of the Board of Management of the Coconut Research Scheme, held in Room No. 202, New Secretariat, Colombo, on February 1, 1933.

Present.—Dr. W. Youngman (in the Chair), Hon'ble Mr. C. W. Bickmore, C.C.S., Acting Financial Secretary, Sir H. Marcus Fernando, Messrs. E. F. Kannangara, J. L. Kotalawala, M.S.C., F. A. Obeyesekere, M.S.C., S. Pararajasingham, J.P., Gate Mudaliyar A. E. Rajapakse, M.S.C., Mr. A. W. Warburton Gray, J.P., U.P.M., and by invitation Dr. R. Child, Chief Technical Officer.

Mr. J. Ferguson had written, regretting his inability to attend.

MINUTES

The minutes of the 18th meeting of the Board of Management, held on October 24, 1932, were confirmed.

It was decided that future meetings should be fixed as far as possible on the first Friday instead of the first Wednesday of the month at 11.15 a.m.

BOARD OF MANAGEMENT

The Chairman reported the appointment of Mr. Kannangara and Mr. F. A. Obeyesekere to the Board and welcomed them as new members.

FINANCE

Owing to delay in completing Building Contracts there remained unexpended balances under various Heads of Votes for 1932, which sums became liabilities for 1933. This delay was due to the difficulty in finding water in the main well, necessitating sinking it much deeper than anticipated, and in the case of the laboratory owing to the discovery of an old well on the site which had to be filled in.

The carrying forward into 1933 of completion of payment for the Gas Plant was of a different nature from the other items. It had only recently been received.

The Board agreed to vote all these expended sums as Supplementary Estimates for 1933.

PROVIDENT FUND

The Board approved of certain amendments to the rules of the Provident Fund, framed upon the advice of the Acting Financial Secretary. The amended rules are intended to effect unity of procedure with the Rubber Research Scheme.

INSTALLATION OF TELEPHONE

The Board agreed, on the proposal of Mr. Warburton Gray, seconded by Sir Marcus Fernando, to guarantee Rs. 380 per annum for five years for the installation of a telephone, this being the Estimate of the Superintendent of Telegraph and Telephones. The originally sanctioned vote was Rs. 300.

PROVISION OF ACCUMULATORS

The matter of installing accumulators in the Power House was referred to the Building Committee.

BUILDINGS

It was reported that the Chief Technical Officer had taken over all the completed buildings, that is all except the Laboratory Block. The Architects expected the latter to be ready for handing over before the end of the month.

Insurance.—The rates quoted by the various companies were read. It was decided to leave the matter of Insurance to the Building Committee.

ESTATE

The Chief Technical Officer's Report on Bandirippuwa Estate was approved, as also, were the Estate Progress Reports for October, November and December, 1932.

Crown Land for experimental purposes.—The Chairman reported that the Board's application for a portion of the Nugagahakelle Forest in the neighbourhood of Bandirippuwa, had been refused by the Executive Committee of Agriculture and Lands.

Mr. Pararajasingham said that there was an area of some 150 acres of good Crown jungle near to his Elapahala Estate in the Chilaw district. Mr. Warburton Gray said that he knew the land referred to and suggested that the Board might try for a piece of the same.

The Board decided that Mr. Pararajasingham and Dr. Child should together look into the matter and that Dr. Child should report as as soon as possible.

Copra drier.—There was considerable discussion on the Chief Technical Officer's report on the "Chula" copra drier. Mr. Warburton Gray said that the question was one of some importance and suggested the desirability of devoting more time to a discussion later, even to have a meeting solely for the purpose. Dr. Child said that he had endeavoured to compress the information in the report as much as possible and could let the Board members have more details if required. The question was accordingly deferred for further consideration, the view being expressed that the whole subject of copra drying might form the subject of a bulletin.

STAFF

The Board had previously decided to consider early this year the question of employing a Soil Chemist. It was proposed by Mr. J. L. Kotalawala and seconded by Mr. S. Pararajasingham that the post should now be advertised.

The Board fixed April 30th as the last day for receiving applications.

DEPARTMENTAL NOTES

PROGRESS REPORT OF THE EXPERIMENT STATION, PERADENIYA

FOR THE MONTHS OF NOVEMBER AND DECEMBER, 1932

GENERAL

THESE two months have seen the commencement of a period of transition. Mr. T. H. Holland, Manager of the Experiment Station, proceeded on leave preparatory to retirement on November 14th. In accordance with the recommendations of the Executive Committee of Agriculture and Lands on Reorganization and Retrenchment in the Department of Agriculture (published in Sessional Paper VIII of 1932) a beginning has been made in the co-ordination of the work of the Farm School and the Experiment Station, having as its aim the bringing of the students into closer touch with the practical side of agriculture. The old system of the Farm School students coming to the Experiment Station for field demonstrations and talks once a week has been superseded; they now take a definite part in the work of the station. The great importance of this work in the training of the students cannot be over-emphasized. Work of an experimental nature, will still be carried out; entire cessation is not contemplated, but the aim will be to produce results which will be of wider application to Ceylon agriculture, and which will tend to meet, in every way possible, the demands both of the village cultivator and of the grower of plantation crops and also experiments for the trial of new crops and determinations connected with the cultivation of them and of already established ones. Several changes which it is neither possible nor necessary to detail here, will follow this change of aim and outlook as a natural sequence of events. The change of name from that of the Experiment Station, Peradeniya, to that of the School Farm (and Experiment Station), Peradeniya indicates in some measure the change in the direction of the work which has begun. The preparation and publication of bi-monthly Progress Reports as in the past, will not be possible in future, but reports of work carried out and in progress will fall into line with those of other divisions of this Department and will be rendered quarterly. These reports will be submitted for publication in *The Tropical Agriculturist.*

TEA

Pruning Experiment

The manuring of the pruning experiment plots has been arranged for and will take place early in the new year. It has been arranged that part of the tea area surrounding the pruning experiment plots will be manured and treated in other respects in the same way as the experimental plots in order to obviate any differences likely to occur as a result of border row or other effects.

Shade Tree Trials

Three out of the four trees of *Albizzia procera* in Tea Field No. 1 were uprooted in October. Two of these were looking unhealthy and showing signs of die-back last June; in August another one was in much the same condition and at the present time the last one is not looking very healthy. They cannot be considered satisfactory shade trees for tea, either for light shade, or for lopping. An attempt, made in July 1929, to establish cuttings from these trees failed.

RUBBER

As the effects of the treatments carried out in the New Avenue Rubber Manurial Experiment during the two-year period ending March 1932 were statistically significant, it has been decided to continue this experiment for at least one year more. The applications of the respective manurial treatments were carried out, therefore, on December 9th in the same manner as previously.

The uprooting of trees in the avenue rubber, reported as begun in the July-August report, was completed with the exception of those trees left for shade and round the boundary for fencing purposes. Similarly the rest of the trees in plots 151-154 (vide May-June report) were uprooted with the Trewhella monkey winch.

CACAO

All the cacao vacancies were supplied, after holing and applying three baskets of cattle manure per hole, with three seeds at stake taken from two selected trees which produce a good type of bean. *Crotalaria anagyroides* was sown round these seeds to act as temporary shade for the young cacao plants.

Vacancies in the cacao selection stock nurseries were also supplied.

The picking of the cacao crop is not yet completed; the weather has been particularly adverse especially as regards an adequate amount of sun for drying purposes. Some difficulties also occurred as a result of the breakdown of the drying room engine during this period, but this was eventually repaired satisfactorily.

COFFEE

The manurial and cultivation experiment carried out since 1921 on a small plot (140 E) of Robusta coffee, comprising altogether 120 bushes, was discontinued as from December 1932. The results of the experiment were given in the report of the work of the Central Experiment Station, Peradeniya included in the Administration Report of the Director of Agriculture for 1931, at the top of page 142. The three respective treatments (viz. cattle manure, forked in with envelope forking, green mulch, no forking; and plain envelope forking) fell due in December, but as neither the cattle manure nor the mulching had exercised any noticeable effect compared with the plain envelope forking it was decided to discontinue this experiment.

CROTON TIGLIUM

The final yield figures of the *Croton tiglium* trees in the six 1/10th acre plots E 121 to E 126, comprising 253 trees, are now available. The total yield was 180·75 lb. of seed of which 114 lb. or 63 per cent. was good seed and 66·75 lb. or 37 per cent., black seed. These trees are approximately 8½ years old, having been planted during the south-west

monsoon season of 1924. In the third week of October 1931, two out of the four rows, 125 trees, were pollarded to about 6 feet producing a lower and more spreading tree from which it is easier to gather the crop. The remaining 127 unpollarded trees received no treatment other than any pruning rendered necessary to remove dead branches. As indicated in the previous report (September-October) pollarding has resulted in a definite increase of crop; the weights quoted in the previous report were for whole, undried *fruits*, comprising kernel, shell and husk. It would appear desirable for purposes of differentiation to restrict the use of the term seed, to the sense in which it is used above, to mean kernel and shell; and the term fruits, as used in the previous report, to mean kernel, shell and the outer husk. The harvesting of the whole crop is now complete and the final figures are 6·3 lb. of fruit per tree from the pollarded trees and 5·5 lb. of fruit per tree from the unpollarded trees—these weights being undried fruit weights. After drying they became reduced to about one quarter of the original weights, with about 50 per cent. husk. The average percentages of good and black seed, as stated above , works out at about 63 per cent. and 37 per cent. respectively. The final result, therefore, is a yield of approximately 2 ounces of good seed and 1 ounce of black seed per tree. This is considered poor and is no doubt due to the Peradeniya climate being too wet for this crop. The harvesting of the crop commenced on June 10th and finished on November 26th and there appears to be no one well defined peak to the crop season; the highest yields, however, were obtained during the latter half of September and October.

CITRUS PLOTS

The programme of weekly spraying with a 2 per cent. solution of a proprietary lime-sulphur compound was discontinued as from the end of November as it was observed that the deposit left on the leaves was becoming extremely marked. The majority of the plants had not a very vigorous appearance and it was considered that this might have been due perhaps to some interference with photosynthesis by the deposit left on the surface of the leaves. Since the recent rain the plants have put out new growth and are looking much healthier.

Citrus canker has continued to give trouble and despite regular spraying in the past a number of the fruits have been affected. An attempt is being made to entirely stop this trouble in the young trees by the rigorous weekly picking off and burning of all canker affected leaves and fruits; this was started at the end of November when spraying was discontinued. It is doubtful, however, if it will be possible to keep this trouble in check on the young plants throughout the year on account of the fact that the infection spreads from the older grape fruit and pumelo trees in a nearby plot which are fairly heavily infected and are too tall to rid of infection in this way.

SOIL EROSION EXPERIMENT

A new soil erosion experiment has been arranged for, to start on January 1st, 1933 the objects being to determine the amounts of soil erosion and also the run-off. Iron roofs have now been made and fitted for the plots in area B to bring them into line with those in area A (vide September-October report). Efforts to secure locally a self recording rain gauge in time for use from the first of January failed.

GREEN MANURE EXPERIMENTS

Green manure experiments are being carried out in collaboration with the Agricultural Chemist. In the experiment to determine the amount of nitrogen fixed by *Calapogonium mucunoides* the plots under this cover crop were allowed to begin to flower fairly freely before uprooting. Owing to the continued wet weather in November flowering was very late and had not started universally on these plots till about December 12th. The cover crop was removed on December 23rd and the necessary sampling and weighing was done on the same day. A cereal crop will be sown on all the plots, and representative samples from each plot will be analysed and the analyses considered in relation to the other records when the final results are available.

IRIYAGAMA DIVISION

The planting up of area 5 was commenced towards the end of October and up to the end of December the planting of 4½ acres had been completed. The total acreage of area 5 is estimated at about 10¼ acres. The eradication of stumps in area 2 was continued; several dying *Gliricidia* trees affected by root disease had to be uprooted and in most cases the trouble could be traced to old stumps which shows the necessity for continuing this work. All the terraces in area 5 were weeded satisfactorily before planting was commenced.

FARM SCHOOL STUDENTS

Both classes of the students at the Farm School attended for work under the reorganised system. The first year students have been given individual plots on which they have put in a part of their time clearing, levelling, draining, weeding the land and dividing it up into plots. The land allotted to each student is divided into four equal areas on one of which three different types of vegetables will be grown; a rotation system with three field crops will be adopted on the other three plots. In addition to some demonstrations and practical work in terracing, levelling, and draining, twenty-two class room lectures were given to the students before they went home for the Christmas vacation. The plots allotted to the students are being maintained by the station labour during absence of the students in vacation.

LIVE-STOCK

The total head of cattle on the station has now been reduced from 58 to 29 by the sale in November of all the spare Kangayam stock, comprising 13 cows, 3 bull calves and 11 cow calves. In addition one brown country calf was sold. From the point of view of expenditure this reduction was an extremely desirable one though the sale had to be held during a period of depression when the prices obtainable are considerably less than they would be in normal times. Considering this the prices realised were satisfactory.

RAINFALL

The rainfall during the period was as follows: November 15·93 inches on 23 days, the heaviest fall being 2·39 inches registered on the 10th. December rainfall was 3·20 inches on 9 days, there being no rain from December 10th to 25th inclusive. This is nearly the lowest December rainfall recorded here for some years; the 1930 record however, was only 1·93 inches on 5 days.

W. C. LESTER-SMITH,
Officer-in-Charge, School Farm
and Experiment Station.

ANIMAL DISEASE RETURN FOR THE MONTH ENDED 28 FEBRUARY, 1933

Province, &c.	Disease	No. of Cases up to Date since Jan. 1st 1933	Fresh Cases	Recoveries	Deaths	Balance Ill	No. Shot
Western	Rinderpest	...	...	...	...	...	...
	Foot-and-mouth disease	22	...	21	1	...	...
	Anthrax	...	...	...	...	..	...
	Rabies (Dogs)	...	...	...	...	...	...
	Piroplasmosis	...	...		...	...	...
Colombo Municipality	Rinderpest	...	...	...	...	...	...
	Foot-and-mouth disease	27	1	25	1	1	...
	Anthrax	2	1	...	2	...	...
	Rabies (Dogs)	8	3	...	...	...	8
	Haemorrhagic Septicaemia	...	...	...	...	...	...
	Black Quarter	...	...	...	...	...	...
	Bovine Tuberculosis	..	...	...	...	...	...
Cattle Quarantine Station	Rinderpest	.	...	...	...	..	...
	Foot-and-mouth disease (Sheep & Goats)	32	13	29	1	2	...
	Anthrax (Sheep & Goats)	30	24	...	30	...	...
Central	Rinderpest	17	..	3	12	...	2
	Foot-and-mouth disease	...	...	...	...	...	...
	Anthrax	8	2	...	8	...	..
	Black Quarter	...	...	...	...	...	...
	Rabies (Dogs)	...	...	...	...	...	...
Southern	Rinderpest	...	...	.	...	...	...
	Foot-and-mouth disease	50	50	50	...	...	...
	Anthrax	...	...	...	...	...	...
	Rabies (Dogs)	...	...	...	...	...	...
Northern	Rinderpest	37	9	9	25	1	2
	Foot-and-mouth disease	4	..	4	...	...	...
	Anthrax	...	...	...	...	...	..
	Black Quarter	..	...	...	...	...	...
	Rabies (Dogs)	..		..	..	...	...
Eastern	Rinderpest	...	...	...	...	...	...
	Foot-and-mouth disease	52	...	51	1	...	...
	Anthrax	...	...	...	...	...	...
North-Western	Rinderpest	...	...	...	...	..	...
	Foot-and-mouth disease	3	3	3	...	...	...
	Anthrax	...	...	..	...	...	...
	Rabies (a bull)	...	...	...	...		..
North-Central	Rinderpest	470	148	80	356	29	5
	Foot-and-mouth disease	...	...	...	...	...	...
	Anthrax	...	...		...	...	...
Uva	Rinderpest Foot-and-mouth disease Anthrax Rabies (Dogs)	FREE					
Sabaragamuwa	Rinderpest	...	...	...	...	...	...
	Foot-and-mouth disease	...	...	...	...	...	...
	Anthrax	..	...	...	...	...	...
	Piroplasmosis	...	...	...	...	...	...
	Haemorrhagic Septicaemia	2	2	...	2	...	...
	Rabies (Dogs)	...	...	...	...	...	...

G. V. S. Office.
Colombo, 9th March, 1933.

M. CRAWFORD,
Govt. Veterinary Surgeon.

METEOROLOGICAL REPORT

FEBRUARY, 1933

Station	Temperature				Humidity		Amount of Cloud	Rainfall		
	Mean Maximum	Difference from Average	Mean Minimum	Difference from Average	Day	Night (from Minimum)		Amount	No. of Rainy Days	Difference from Average
	°	°	°	°	%	%		Inches		Inches
Colombo -	86·2	− 0·8	71·9	+ 0·3	72	90	4·2	2·60	8	+ 0·41
Puttalam -	87·6	− 0·8	70·4	+ 0·7	70	93	3·4	0·69	5	− 0·60
Mannar -	85·5	− 1·7	73·7	+ 0·3	68	86	3·8	1·08	1	− 0·21
Jaffna -	85·9	+ 0·3	70·2	− 1·5	72	95	4·1	0·50	1	− 0·75
Trincomalee -	82·8	− 0·1	75·6	− 0·3	74	82	4·4	0·68	5	− 1·48
Batticaloa -	82·7	− 0·4	73·4	− 0·1	76	88	3·8	4·78	10	+ 1·25
Hambantota -	85·5	− 0·9	72·6	− 0·1	75	90	3·6	2·10	8	+ 0·69
Galle -	85·0	− 1·0	73·4	+ 0·2	76	93	4·7	2·49	14	− 0·42
Ratnapura -	90·5	− 1·7	71·7	+ 0·6	70	93	5·4	8·37	17	+ 3·76
A'pura -	86·2	− 0·7	70·6	+ 1·3	74	93	5·3	0·69	5	− 0·89
Kurunegala -	88·5	− 1·7	69·9	+ 0·4	63	93	5·3	1·93	5	+ 0·12
Kandy -	84·7	− 1·7	67·0	+ 0·2	62	87	4·5	4·90	6	+ 2·60
Badulla -	78·8	− 0·2	63·6	+ 1·2	76	97	5·2	4·68	11	+ 1·72
Diyatalawa -	74·5	− 0·8	57·4	+ 2·1	74	88	5·8	4·99	10	+ 2·66
Hakgala -	69·7	− 1·7	50·0	− 0·1	78	93	5·1	6·47	13	+ 3·07
N'Eliya -	69·4	− 0·9	45·4	+ 2·5	75	90	5·4	1·71	11	− 0·33

The rainfall of February was generally in excess over the greater part of the Island, the chief exception being the northern parts. Rainfall averages are low in February, and even with this excess, less than a score of stations reported as much as 10 inches for the month and only one station, Detanagalla, over 15 inches. A few stations in the north of the Island reported no rain at all.

Last month's wet spell continued into February, but conditions became more settled towards the end of the first week and fairly fine weather prevailed till about the 18th. Thunderstorm activity was well in evidence during the last ten days of the month.

There were only two falls of over 5 inches in a day, 5·58 inches at Meeriabedde on the 18th-19th and 5·30 inches at Alutnuwara on the 1st-2nd.

Temperatures were consistently below average by day and, on the whole, above average by night. Humidity and cloud were above normal for the month. The general direction of the wind was north-easterly.

D. T. E. DASSANAYAKE,
Actg. Supdt., Observatory.